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A 90-foot, tilt-down tower provides easy turbine access for Vince Culp of Energy Unlimited.

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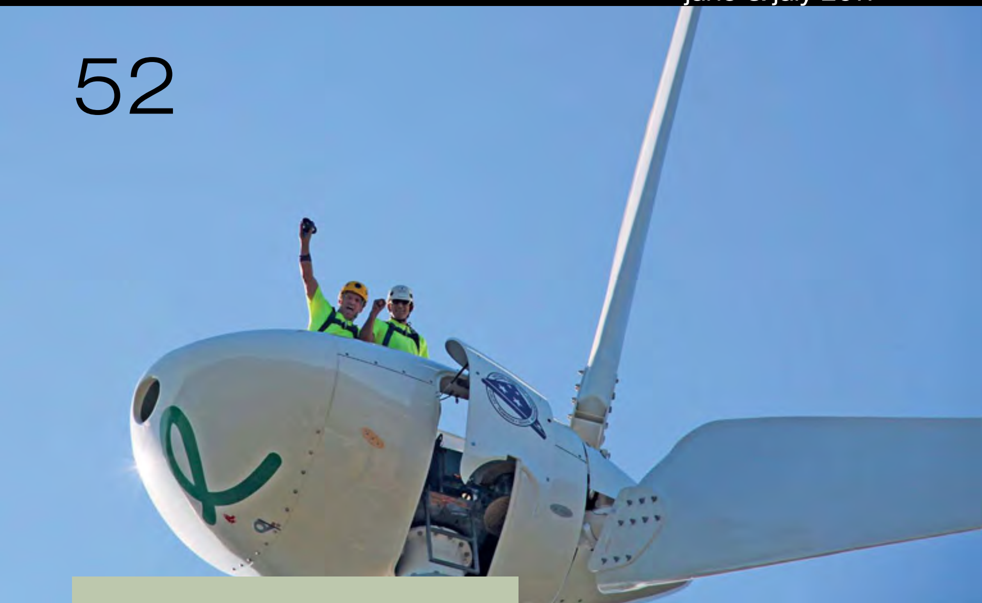

Main Features

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Vince Culp of Energy Unlimited inspects an Endurance S-343 wind turbine in preparation for raising it into the wind.

Photo: Shawn Schreiner

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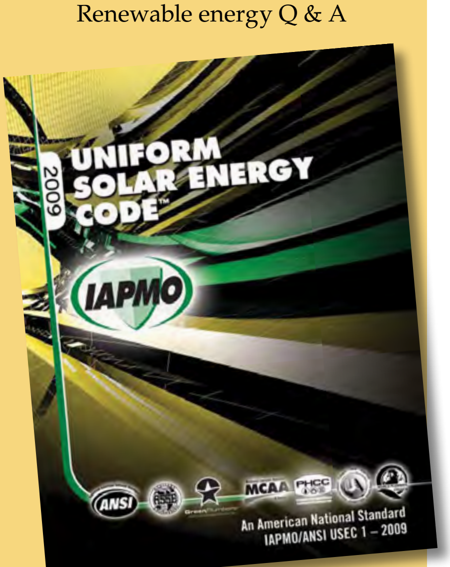

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In Back

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A Better Base Load

Shawn Schreiner

Since the onset of Japan's post-tsunami nuclear crisis, I've been fielding energy-related questions from friends and family. The common thread is along the lines of, "How do we replace nuclear with solar?" The answer is a complicated one. It gets into descriptions of conventional base-load energy sources like nuclear, coal, and hydro-electricity, and what are currently considered to be intermittent energy sources, namely solar- and wind-powered electricity. Understanding this interrelationship is key, and Home Power's solar-electric system (see photo) can serve as an example.

On an annual basis, our company's PV array generates more than enough energy to offset our local staff's usage, including energy-intensive space heating and air-conditioning. But like the majority of grid-tied solar-electric installations, Home Power's system does not include energy storage. During cloudy weather, our building often requires more energy than our PV array generates, and at night, we run on grid electricity entirely. In both of these instances, we rely on the conventional energy sources that make up the bulk of base-load generation.

Here in Oregon, the primary electricity source is hydro, mostly coming from the Columbia River basin. Another 30% of the electricity generated in the state is fueled by natural gas, with coal contributing about 7%. In most states, nuclear power is also part of the mix. Point being, if you install a PV system, and even if it offsets more than your cumulative usage, you're not off the hook. You will still be tapping into primarily nonrenewable base-load energy sources on a daily basis.

That's the reality today, but it won't be in the future. As renewable generation capacity increases and continues to come down in cost, a decreasing percentage of the base load will be made up of conventional energy sources. And as the grid gets smarter, it will include more sophisticated weather forecasting and energy-source control, which will effectively manage and distribute clean energy both locally and regionally. Renewables will no longer be an intermittent energy source—they'll be the core component of a better base load.

—Joe Schwartz, for the *Home Power* crew

Think About It...

"We have oil dependence problems. We have nuclear power safety issues and waste disposal problems. We have the difficulties of getting a lot of the renewables like wind and solar up to scale and we have a really hard challenge convincing people that energy efficiency is actually the most effective way to lower our energy costs and usage."

—Hillary Clinton, Secretary of State, March 16, 2011

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Solar Gardens a Growing Trend

For years, Steffen Bradley considered the idea of putting PV modules on his 1950s ranch-style home in Ellensburg, Washington. Every now and again, he'd take a lap around his yard, hoping this time he'd find a novel way to overcome shading issues posed by the many trees on his and his neighbors' lots. For urban solar systems, it's a common challenge encountered in older neighborhoods—big, beautiful trees make the community attractive but prevent good solar access on roofs.

Fortunately, alternatives are springing up in communities across the country. Steffen counts himself lucky to live in one that has embraced an innovative solution to on-site solar: community solar arrays, sometimes called community solar gardens or farms. The concept? Provide a large, centralized PV power plant, allowing individuals who are otherwise unable to put PV on their roofs to invest in and benefit from a local, clean, renewable energy source.

With help from the Bonneville Environmental Foundation and Washington State University's Northwest Solar Center, the community built one of the first solar parks in the United States. The Ellensburg Community Renewable Park has grown from 36 to 111 kW through buy-ins from local residents, who benefit from the park's energy generation. Residents can buy in as much as they'd like—up to the point of zeroing out their monthly electricity bills.

Courtesy City of Ellensburg

Steffen and his wife, Carin, invested $1,000 in the second phase of the park and plan to invest more in future phases. In return, the couple receives credits on their electricity bills for a portion of the system's production over the next 20 years. They also qualify for the $0.30 per kWh state solar incentive.

No Solar Site? No Problem

Solar gardens put emphasis on small- and medium-scale distributed generation. Unlike large utility-scale solar facilities, these smaller, shared systems are closer to home, ideally on an existing, large rooftop or otherwise unusable land.

The primary push for these shared systems stems from the fact that on-site generation is not feasible for the majority of people. According to a 2008 study by the National Renewable Energy Laboratory, only 22% to 27% of residential buildings are suitable for hosting a PV system.

Most recently, the concept has gained momentum in Colorado, in part due to increasing concerns over "energy sprawl" from large-scale PV farms in the San Luis Valley. Aside from aesthetic concerns for the landscape, a point of contention among area residents was that the energy generated was not being sold locally, but rather exported to the Denver area.

"Locally produced solar is the best kind of solar. Using rooftop solar gardens instead of industrial solar farms helps protect important landscapes like Colorado's San Luis Valley," says Joy Hughes, founder of the Solar Garden Institute, a nonprofit cooperative that advocates community-based energy development. The group was instrumental in getting state lawmakers to pass the Community Solar Gardens Act last year.

The new legislation mandates that the state's investor-owned utilities provide net-metering credits to those who subscribe to solar gardens. The legislation allows groups of at least 10 subscribers to collectively own a share of a solar system in the county where they reside.

Ways To Grow Solar

Other utilities have followed Ellensburg's example and set up similar programs (see map on

Courtesy City of St. George

pages 16–17). At least a half dozen other entities and citizen groups are developing community-shared systems. That number is expected to rise as regulatory hurdles come down and models evolve.

Barriers to third-party power purchase agreements present a significant obstacle for community solar arrays, says Laurel Varnado, a policy analyst for the North Carolina Solar Center.

"If the state doesn't have a vehicle for third-party power purchase agreements (PPAs)," she says, "then the group is forced to resort to cumbersome contractual agreements with their local utility to sell power to the utility."

A variety of economic structures, each with unique advantages and disadvantages, has been used to bring these systems on-line. Leases and PPAs are most common, but in some cases, subscribers form an organization such as a limited liability corporation, a co-op, or a nonprofit.

Many programs utilize some form of virtual net-metering, which allows multiple individuals to receive credits on their electricity bills for a portion of one PV system's output—though specific rules vary.

Currently, only nine states have laws in place that allow community or shared-system net-metering. Each has taken a different approach, adopting unique policies for dealing with joint ownership and billing, utility involvement, and meter aggregation, according to Varnado. For example, the parameters for participants' geographic dispersal and incentives eligibility vary from state to state.

Other states, including Maryland and Connecticut, are considering changing their net-metering laws to address metering issues related to community solar, Varnado says. At the federal level, the Solar Uniting Neighborhoods Act, sponsored by Senator Mark Udall (D-Colo.), aims to extend the existing 30% federal renewable energy tax credit to group-owned solar installations.

Breaking Down the Barriers

A roadblock for grassroots efforts is that subscriptions to solar gardens are, by definition, financial securities and subject to federal and state regulations, says David Brosch, a founding member of the University Park Community Solar project in Maryland.

Brosch and his neighbors in University Park have done what few others have, creating a community solar garden that is independently run and funded. The project—a 24 kW array on the south-facing roof of a local church—took more than two years to bring to fruition. Their inspiration came from the fact that many of their homes did not have suitable solar access due the area's expansive canopy of trees.

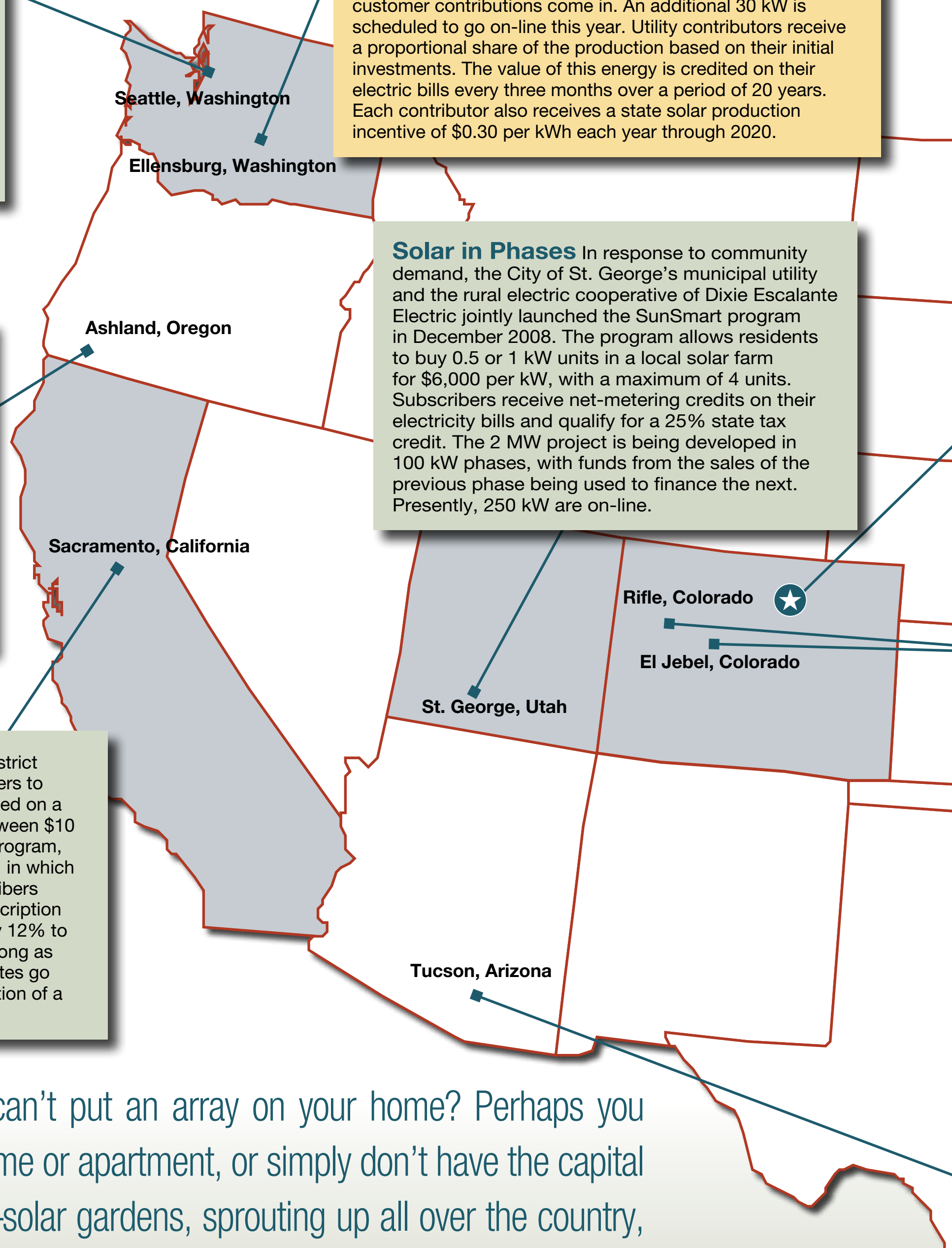
"We were a bit naïve going into the process. Securities regulations are rather complex, and each state is different," Brosch says. "We quickly learned that it is very difficult for the small folks to do what the big companies do all the time."

The group—University Park Community Solar (UPCS)—started from scratch, working through all the issues of insurance, utility connections, and accounting. Attorneys and advisors helped them explore the pros and cons of how different businesses handle tax structure, ability to pass through profits, and eligibility for available incentives.

Ultimately, UPCS formed a limited liability corporation and took on 35 investors, at levels ranging from $2,000 to $15,000, to fund the $130,000 installation. The group set up a PPA, in which the church buys the generation from the system for 20 years, at a rate slightly lower than the utility rate. They also played a hand in helping change the state's net-metering law so that the utility pays the group for any excess generation fed back to the grid (see map).

To comply with state securities regulations, UPCS could not have more than 35 investors and had to steer clear of certain phrases in advertising and other marketing materials, Bosch says. The group circumvented federal security regulations by accepting only in-state investors.

(continued on page 18)



Gardens in the Park This summer, Seattle City Light will launch its pilot community solar program with a 24 kW PV array. In partnership with Seattle Parks and Recreation, the municipal utility is building three picnic shelters in Jefferson Park and equipping each roof with PV modules. Subscribers can purchase the output from a maximum of two "units" for an up-front cost of $600 per unit. Each unit is estimated to produce roughly 48 kWh per month. Through 2020, subscribers will receive credits on their electricity bills and qualify for a $1.08 per kWh production incentive through the state. This initial project is expected to sell out fast, and additional arrays are in development.

A Shining Example The concept originated in 2004, but it wasn't until 2006 that the City of Ellensburg's municipal utility installed the first 36 kW phase of the Ellensburg Community Renewable Park. The system—prominently located along a highway for maximum exposure—has since grown to 111 kW. The project continues to grow as utility customer contributions come in. An additional 30 kW is scheduled to go on-line this year. Utility contributors receive a proportional share of the production based on their initial investments. The value of this energy is credited on their electric bills every three months over a period of 20 years. Each contributor also receives a state solar production incentive of $0.30 per kWh each year through 2020.

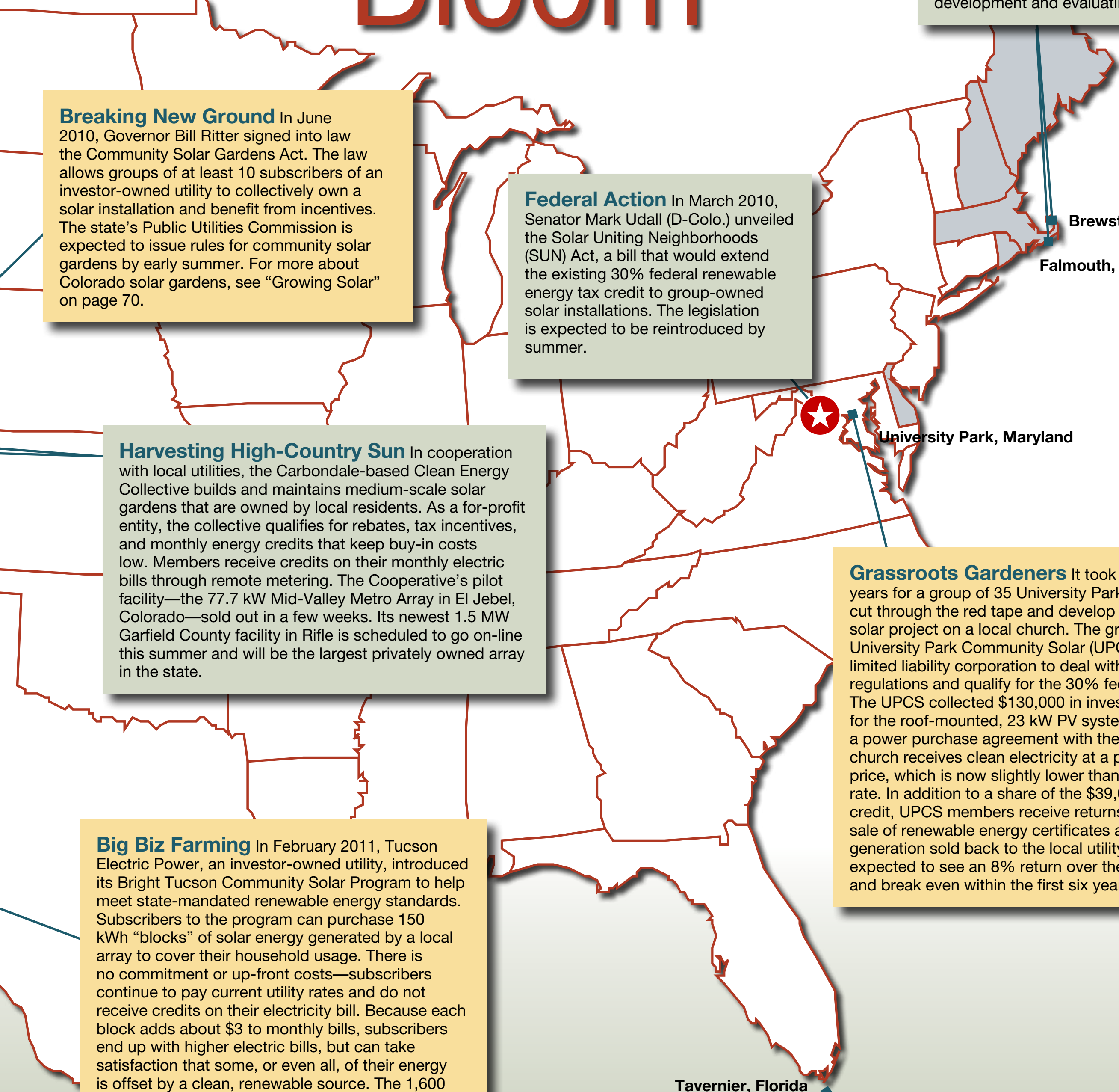
An Energized Community In the city of Ashland, where a thick tree canopy prevents good solar access for many homes, the Solar Pioneer Program allows residents and businesses to purchase the output from a 64 kW roof-mounted PV system located on the City's service center. The charge for one module is $743, with the cost stepping down yearly and no maximum purchase restrictions. For the life of the 20-year program, subscribers receive a yearly credit on their electric bills based on current net-metering rates, and own the renewable energy certificates associated with the modules. The project came on-line in 2009, and so far, about half of the array is under contract.

Solar in Phases In response to community demand, the City of St. George's municipal utility and the rural electric cooperative of Dixie Escalante Electric jointly launched the SunSmart program in December 2008. The program allows residents to buy 0.5 or 1 kW units in a local solar farm for $6,000 per kW, with a maximum of 4 units. Subscribers receive net-metering credits on their electricity bills and qualify for a 25% state tax credit. The 2 MW project is being developed in 100 kW phases, with funds from the sales of the previous phase being used to finance the next. Presently, 250 kW are on-line.

A Balancing Act In 2007, Sacramento Municipal Utility District launched a program called SolarShares, which allows subscribers to source up to 40% of their energy from a 1 MW solar array located on a local turkey farm. Subscribers pay a monthly fee—typically between $10 and $127—to subscribe to "shares" in the array. Through the program, subscribers essentially enter into a power purchase agreement, in which the utility buys the output from the subscribers' shares. Subscribers receive net-metering credits on their monthly bills, but the subscription fee typically cancels out any credits. The program adds roughly 12% to a subscriber's bill. Subscribers are able to lock in a rate for as long as they are SMUD customers and will save money as electricity rates go up. Shares in the first array are currently sold out, but construction of a second 1 MW array is expected early next year.

Interested in solar electricity but can't put an array on your home? Perhaps you have a shaded property, rent a home or apartment, or simply don't have the capital for an entire system. No matter—solar gardens, sprouting up all over the country, allow customers to use renewable energy without having a rooftop system at their residences. Also known as solar farms, this strategy is a viable alternative, giving individuals the opportunity to purchase a portion of an off-site array and benefit from its clean energy generation. Organizers, big and small, are breaking new ground across the country, cultivating a variety of models and financial structures. The movement is young but blossoming fast, with nurturing from newly enacted energy policies at the local, state, and federal levels.

Solar Gardens Bloom



Planting Solar Seeds Cape Cod residents formed limited liability corporations in Brewster and Falmouth with the hope of developing community solar gardens under the Massachusetts Green Communities Act of 2008. Both groups are working with My Generation Energy of South Dennis—a for-profit entity pioneering an innovative community solar garden (CSG) model in the region. The Brewster CSG won support from the town council and should be on line by the year's end. The Falmouth CSG is still in the early stages of development and evaluating potential sites.

Breaking New Ground In June 2010, Governor Bill Ritter signed into law the Community Solar Gardens Act. The law allows groups of at least 10 subscribers of an investor-owned utility to collectively own a solar installation and benefit from incentives. The state's Public Utilities Commission is expected to issue rules for community solar gardens by early summer. For more about Colorado solar gardens, see "Growing Solar" on page 70.

Federal Action In March 2010, Senator Mark Udall (D-Colo.) unveiled the Solar Uniting Neighborhoods (SUN) Act, a bill that would extend the existing 30% federal renewable energy tax credit to group-owned solar installations. The legislation is expected to be reintroduced by summer.

Harvesting High-Country Sun In cooperation with local utilities, the Carbondale-based Clean Energy Collective builds and maintains medium-scale solar gardens that are owned by local residents. As a for-profit entity, the collective qualifies for rebates, tax incentives, and monthly energy credits that keep buy-in costs low. Members receive credits on their monthly electric bills through remote metering. The Cooperative's pilot facility—the 77.7 kW Mid-Valley Metro Array in El Jebel, Colorado—sold out in a few weeks. Its newest 1.5 MW Garfield County facility in Rifle is scheduled to go on-line this summer and will be the largest privately owned array in the state.

Grassroots Gardeners It took more than two years for a group of 35 University Park residents to cut through the red tape and develop a community solar project on a local church. The group—known as University Park Community Solar (UPCS)—formed a limited liability corporation to deal with the securities regulations and qualify for the 30% federal tax credit. The UPCS collected $130,000 in investments to pay for the roof-mounted, 23 kW PV system. Through a power purchase agreement with the UPCS, the church receives clean electricity at a predictable price, which is now slightly lower than the utility rate. In addition to a share of the $39,000 federal tax credit, UPCS members receive returns through the sale of renewable energy certificates and any excess generation sold back to the local utility. Members are expected to see an 8% return over the 20-year period and break even within the first six years.

Big Biz Farming In February 2011, Tucson Electric Power, an investor-owned utility, introduced its Bright Tucson Community Solar Program to help meet state-mandated renewable energy standards. Subscribers to the program can purchase 150 kWh "blocks" of solar energy generated by a local array to cover their household usage. There is no commitment or up-front costs—subscribers continue to pay current utility rates and do not receive credits on their electricity bill. Because each block adds about $3 to monthly bills, subscribers end up with higher electric bills, but can take satisfaction that some, or even all, of their energy is offset by a clean, renewable source. The 1,600 blocks of a first 1.6 MW PV array are nearly sold out, but a new 2 MW PV array will be on-line by early summer, and more arrays are in the works.

The Sunshine State Through its Simple Solar program, Florida Keys Electric Cooperative allows customers to lease PV modules at the cooperative's solar farm in Marathon. In return for leasing one or more modules for $999 each over 25 years, members receive monthly credits on their bill for the full retail value of the electricity generated by their leased modules. The program rolled out in early 2010 and was off to a slow start, only attracting 10 subscribers as of early spring 2011.

Now, the group has plans for a larger community array and hopes to receive an exception through the state securities commission that will allow the project to take on as many as 125 investors.

Pioneers & Pros

While Luke Hinkle admires the persistence of the UPCS, he recommends that people leave the nuances to professionals. "It is an extremely complicated process. There's no need for small groups to reinvent the wheel over and over again," says Hinkle, who is credited with coining the term "solar garden."

Under the umbrella of his company—My Generation Energy, a solar energy installation and development company in South Dennis, Massachusetts—Hinkle intends to establish a solar garden consulting service to help groups implement a unique solar garden model he developed. The pilot program is expected to launch in Brewster later this year.

Other companies are breaking into the market as well. Seattle-based Tangerine Solar is working with groups, large and small, to develop community solar arrays through its SolarSlice model. The Clean Energy Collective LLC, of Carbondale, Colorado, is pioneering a unique model for medium-scale systems that uses a proprietary remote metering system (see "Green Power for your Home" in this issue).

To help streamline the process for utility companies, the RE policy organization Interstate Renewable Energy Council has developed model program rules that can be adapted to each group's circumstances and the policy preferences within their respective states.

The Finer Details

While there are many benefits to shared systems—lower up-front costs and a hedge against rising electricity rates—there are tradeoffs. In most cases, the controlling entity retains ownership of the renewable energy certificates associated with the system. This means subscribers cannot legally claim to use "clean" energy.

In addition, the rate of return on solar gardens tends to be lower than with on-site residential systems. Subscribers may see a modest reduction in their electricity bills, but fees and buy-in costs often cancel out any savings. On the upside, subscribers are not responsible for the system's maintenance and operations costs.

For Joan and Myron Porter, the City of St. George's SunSmart program ended up being a perfect fit. The retired couple first subscribed to the program while living in a townhouse community where PV systems were prohibited. They've since moved to a new home in town and were able to transfer their shares with ease. "We get a small credit on our bill each month," Joan says. "We're not getting rich, but we're doing what we think is right."

—Kelly Davidson

Courtesy Pam Rutter

Renewable Energy Fairs

Renewable energy fairs are the ultimate way of getting shared, personal experience with RE, alternative transportation, and green building technologies. At these fun events, you'll find workshops by the pros, exhibits, food, music, kids' events, and an all-around good time with all-around good folks. See you there!

Courtesy Rocky Mountain Sustainable Living Association (2)

Northwest & Alaska

July 16 • Northwest SolarFest
Shoreline, WA • www.shorelinesolar.org

July 29–31 • SolWest Renewable Energy Fair
John Day, OR • www.solwest.org

August 13 • Alaska Renewable Energy Fair
Anchorage, AK • www.realaska.org

Central

September 3–4 • Crestone Energy Fair
Crestone, CO • www.crestonepeak.org

September 17–18 • Rocky Mt. Sustainable Living Fair
Fort Collins, CO • www.sustainablelivingfair.org

Southwest

August 27–28 • Solar Fiesta
Albuquerque, NM • www.nmsea.org

September 23–25 • Renewable Energy Roundup & Green Living Fair • Fredericksburg, TX • www.theroundup.org

Courtesy Southern Energy & Environment Expo

2011

Courtesy SolWest

Northeast

June 10–12 • Solar & Wind Expo
King of Prussia, PA • www.thesolarandwindexpo.com

July 15–17 • SolarFest: The New England Renewable Energy Festival • Tinmouth, VT • www.solarfest.org

September 16–18 • Pennsylvania Renewable Energy & Sustainable Living Festival • Kempton, PA • www.paenergyfest.com

Midwest

June 17–19 • The Energy Fair (aka MREF)
Custer, WI • www.midwestrenew.org

June 24–26 • Michigan Energy Fair
Ludington, MI • www.glrea.org

August 13–14 • Illinois Renewable Energy & Sustainable Lifestyle Fair • Oregon, IL • www.illinoisrenew.org

August 19-20 • Polk County Energy Fair
St. Croix Falls, WI • www.polkcountyenergyfair.com

South

August 19–21 • Southern Energy & Environment Expo
Fletcher, NC • www.seeexpo.com

Courtesy Rocky Mountain Sustainable Living Association

Courtesy Dan Hoffman Photography

For the Pros

June 14–15 • Small Wind Conference • Stevens Point, WI • www.smallwindconference.com

July 12–14 • Intersolar North America • San Francisco, CA • www.intersolar.us

October 17–20 • Solar Power International • Dallas, TX • www.solarpowerinternational.com

Dirty Business

Clean Coal & the Battle for Our Energy Future

Courtesy Center for Investigative Reporting

Founded in 1977, the Center for Investigative Reporting (CIR) has a long history of revealing injustice through award-winning reporting. In its latest documentary, the Berkeley, California-based nonprofit aims for nothing less, taking on the coal industry and calling clean coal a dirty lie.

The 90-minute film—*Dirty Business: Clean Coal and the Battle for Our Energy Future*—seeks answers to three burning questions: Can coal ever really be made "clean"? If we were to try to wean ourselves off coal, how would we keep the lights on? Is renewable energy ready for prime time?

In the film, *Rolling Stone* reporter Jeff Goodell—author of *Big Coal: The Dirty Secret Behind America's Energy Future*—digs deep to expose the real costs of the world's reliance on coal-fired electricity. Startling truths are revealed through a series of stories shot in China, Saskatchewan, Kansas, West Virginia, Nevada, and New York. Stories range from a Kansas cowboy saving his cattle ranch with wind power to doctors assessing the link between coal pollution and abnormalities among newborn babies in China, where a new coal plant goes up every week.

The film was written, produced and directed by Peter Bull and co-produced by Justin Weinstein, the duo that produced the PBS Frontline and CIR co-production *Hot Politics,* which examined the politics of global warming.

To learn more about the film, view the trailer, or order a DVD, visit www.dirtybusinessthefilm.com.

Solmetric PVA-600 PV Analyzer

Courtesy Solmetric

The PV Analyzer (MSRP $2,595) from Solmetric (www.solmetric.com) is a current/voltage (I-V) and power/voltage (P-V) curve tracer that can be used for testing the performance of module strings and individual modules. Information is wirelessly transmitted and displayed on the user's PC (using the PV Analyzer software for Windows).

Developed with the entire life cycle of the PV array in mind, the Analyzer can be used during start-up testing and commissioning, and for periodic checkups and troubleshooting. Capturing I-V and P-V curves during commissioning provides detailed performance baselines for future comparisons. Comparing the baseline readings to another trace allows users to see how much degradation has occurred and spot problems with individual modules or module strings (see "Potential PV Problems & New Tools for Troubleshooting" in this issue). The Analyzer also can help determine whether underperformance problems are in the array or the inverter(s). In times of prolonged cloudy weather and less-than-expected electrical production, the PV Analyzer also gives installers a way to assure owners that their PV arrays are functioning properly.

Several accessories are optional: the PVA (irradiance and temperature) Wireless Sensor Kit ($1,495), used to improve measurement accuracy; I-V Data Analysis Software tool for Microsoft Excel ($95), for charting measurements; and Test Leads ($125) to adapt MC-4 connectors to alligator clips.

—Justine Sanchez

SMA America Sunny Wireless WebBox

SMA America's (www.sma-america.com) Sunny WebBox, which uploads PV system information to the SMA Sunny Portal, can now collect information wirelessly from SMA inverters. (The original WebBox needed an RS485 cable connection to the inverter.)

With a 120 VAC outlet and an Ethernet connection to a local router, users can now locate the WebBox in alternate locations. The box must be located in a weather-protected environment, but will work in temperatures from -4°F to 149°F.

Its Bluetooth signal range depends on the obstructions (walls, etc.) between devices. Maximum unobstructed communication range is 164 feet, but is extendable to 328 feet with the optional SMA Bluetooth Repeater. Except for the HF models, the inverters require installing a Bluetooth Piggyback card to communicate wirelessly to the WebBox.

—Justine Sanchez

Courtesy SMA America

The Solar Women of Totogalpa

A group of rural Nicaraguan women cook up a winning recipe for a solar-powered restaurant.

A group of women in rural northern Nicaragua, where 20 years ago a war raged, are empowering their community with renewable energy. The Mujeres Solares de Totogalpa (Solar Women of Totogalpa; SWT) is a cooperative that offers solar products and serves as a model of economic, ecological, and social sustainability.

The story of the solar women of Totogalpa begins in 1999, when Grupo Fenix—a group founded by university students from Managua, Nicaragua, led by engineering professor Susan Kinne—received a grant to reintegrate land mine victims into society. Their approach? Training them to build PV modules (see "Solar Electricity in the Nicaragua Hills" in *HP97*).

The group focused their efforts on Sabana Grande, an agricultural community of 200 families in the mountains of Totogalpa, about 20 miles from the Honduran border. Land mines scattered throughout the region had left many civilians disabled.

Grupo Fenix hosted workshops, training land mine survivors to assemble their own PV modules using discarded PV cells. The group also donated a few solar cookers to the community. This low-tech tool immediately interested the women in the community—in Nicaragua, where at least 90% of the rural population cooks over an open fire, respiratory diseases are the leading cause of death for women.

Before long, the women began building their own solar cookers and adapting them for specific uses. The cookers do not replace wood entirely but reduce the amount of wood needed for cooking—and the women's smoke exposure.

The Key Ingredients

In 2003, with the support of Grupo Fenix, the women organized into the *Mujeres Solares de Totogalpa*. In 2010, they became an official Nicaraguan cooperative. The SWT had been selling and building solar ovens out of members' houses, but they needed more room to work. They dreamed of having a solar restaurant where they could showcase their solar-cooked food and teach the public about solar ovens. But they were missing the key ingredients: funding and a piece of land.

The SWT solar cooker is based on one originally developed by the Central American Solar Energy Project (www.solaroven.org). A box cooker, with one reflector and a door in the front, sits on a wheeled stand so it can be moved easily.

Courtesy Laurie Stone

The women turned to Grupo Fenix for guidance, securing a grant from the Oklahoma-based Noble Foundation in 2005, and acquiring three acres of donated land along the Pan-American highway to Honduras. A local architect helped them develop a plan for a solar campus that could grow one building at a time.

The first Solar Center building—constructed with adobe blocks that the women made—got underway in 2005, with the women doing all of the heavy lifting. More than 6,000 adobe blocks were made for the building, all on volunteer time. In fact, in one year alone, the women contributed more than 8,000 volunteer hours to the building's construction.

In December 2007, the women inaugurated their first building, housing an office and warehouse, as well as workshop and meeting spaces. One of the products the women are most proud

of, and that visitors most often request, is their solar-roasted coffee. Coffee is Nicaragua's biggest export crop, and the best coffee beans are sent to the United States and Canada, leaving Nicaraguans with a bitter cup of coffee from the green beans that remain. However, the women figured out that if they roast the coffee beans in the solar oven, instead of over an open fire (the traditional method), the bitterness mellows, leaving a rich and delicious flavor.

The women also produce jams canned in the solar ovens, solar-dried fruits, medicinal herbs, and solar-baked cookies and cakes. However, the women really desired a venue to sell their products and to showcase their solar ovens, and their dream of having a solar restaurant continued.

Courtesy Laurie Stone (2)

Green Hours & Nano-Loans

The SWT faced many challenges during the two years it took to build the center—weather, lack of construction skills, tight finances, and internal struggles. Some women put in more volunteer hours than others, and this caused some discord. To alleviate some of the tension, the group decided they would keep track of the volunteer hours. With the help of volunteer Charlotte Ross, a student of economics, the women went a step further and devised a system of "green hours."

Each woman earns one credit for every hour worked. The women can redeem their credits to purchase items in their "green store," open once a month, where donated items—ranging from solar cookers and PV systems to bed linens and clothes—are sold. Members have the option to purchase items with hours or with cash, and the income generated is used to buy items that the group needs.

As more visitors came to the Solar Center, the women decided they needed better guest accommodations—a separate room with a bed, mosquito net, and lockable door. But creating this addition to their homes required cash for materials, which the women didn't have.

Under Ross's guidance, a nano-loan program was established, providing $150 home-improvement loans. Participants use income from renting the rooms to repay their loans, while income from meals served to guests goes directly to the women and their families.

The loan program has been wildly successful: 19 of the 20 families represented in the SWT now have guest rooms in their homes, and there has been a 100% loan payback rate.

Recipe for Success

In 2009, the women secured international grants to begin work on their solar restaurant. The restaurant will offer meals prepared with produce from their organic gardens, using innovative cooking methods—solar cookers, parabolic cookers, solar dryers, and, perhaps, a range fueled by methane gas produced in a biodigester.

The restaurant will run entirely on solar power. The first PV array was installed in December 2010 during a Solar Energy International workshop. Four 220-watt modules will power DC lights and AC appliances, such as a blender and microwave. Eventually, another PV system will be added to run a refrigerator.

—Laurie Guevara-Stone, International Program Manager at Solar Energy International

Courtesy Laurie Stone

Solar as the Main Course

One of the SWT's biggest accomplishments has been the electrification of all of its members' households. In Nicaragua, only 55% of the population has access to electricity and less than 1% of that comes from solar electricity—though that percentage is increasing rapidly in rural areas. In Totogalpa, only 15% of the population has access to electricity and less than 1% comes from solar power. But within the SWT, 100% of members have access to electricity and 54% of their households are powered with solar energy.

Solar Energy Supports Clean Water

Courtesy ReVision Energy

Aqua America hired ReVision Energy to provide solar energy for a modern water filtration system, extending their corporate commitment to green energy. In Rockport, Maine, the new, state-of-the-art filtration system provides purified drinking water to the communities of Rockport, Camden, and Rockland, and replaces older equipment that relied more heavily on chlorination. The new equipment needs up to 2,500 gallons per day of backwash water, heated to 95°F, to clean the filters. The equipment includes a 45 kW electric heater as the heat source, which accounts for an annual energy load of about 100,000 kWh. Aqua America saw the potential for replacing this dependence on utility-produced electricity with clean, renewable energy.

Originally, the company had proposed a ground-mounted solar thermal array that was designed to meet about 75% of the annual load. However, this system required protecting the array from winter frost heaves, and installing several hundred feet of underground piping and a 1,000-gallon storage tank in a basement separate from the filtration plant. ReVision Energy proposed an alternative design—a roof-mounted hybrid solution that uses both solar thermal and photovoltaic technologies. This design significantly reduces system maintenance, while having the added advantage of cashing in on Maine's net-metering agreements.

ReVision's team designed a 16-collector thermal array that fits on the operations and filtration building's south-facing roof, along with 16.1 kW of PV modules mounted on adjacent triangular sections of the roof. The solar thermal system will provide an estimated 55% of the annual heating element load; the PV system should provide approximately 21%.

The hybrid system offsets three-quarters of the load, year-round, in a challenging climate. In the summer, the solar thermal array fully heats the backwash water. The grid-tied PV system generates about 21,000 kWh each year to offset the remaining heating element load.

—William Behrens

Project Specs

Project name: Mirror Lake water treatment facility
System types: Grid-tied PV & antifreeze-based solar hot water
Installer: ReVision Energy
Location: Rockport, Maine
Latitude: 44.2°N
Resource: Solar

PV System

Number of modules: 70
Manufacturer & model: Solon Blue 220/01
Module rating: 230 W STC
Inverters: Solectria PVI 15
Inverter rated output: 15 kW
Array installation: Roof-mounted
Roofing material: Asphalt shingles
Array azimuth: 205°
Tilt: 31°
System capacity: 16.1 STC
Average annual production: 20,828 AC kWh
Heating load offset: 21%

Solar Thermal

Number of collectors: 16
Model: Chromagen SLCR40 flat-plate
Collector installation: Roof-mounted
Heat-transfer fluid: 40% propylene glycol; 60% water
Circulation pumps: Taco 2400-20 (on glycol side); March magnetic drive chemical pump (for chlorinated water side)
Pump controller: Resol BS Plus & Resol BS/2
Array azimuth: 205°
Tilt: 31°
System capacity: 640,000 Btu/hr. (max.)
Average annual production: 55,000 kWh
Heating load offset: 55%

Sizing Residential SHW Systems

Courtesy SunEarth

In North America, SHW designers and installers choose from at least four methods to determine the collector surface area needed for solar water heating. Many use a quick sizing approximation or the U.S. Department of Energy's (DOE) published guidelines for small residential systems. In areas where incentives are calculated using the OG-300 solar system performance estimates from Solar Rating and Certification Corporation, designers, installers, and program administrators mine the SRCC database to find estimated system performance for many U.S. locations. Larger space heating systems, and commercial and industrial SHW systems, use a more precise method of sizing incorporated into SHW sizing software.

Small systems have constraints that limit the accuracy of sizing the system. Solar collectors are only made in a few sizes and the same goes for storage tanks. A typical manufacturer of either flat-plate or evacuated-tube collectors will only offer three or four collector sizes. Residential storage tanks (electric water heaters) come in 30, 40, 50, 66, 80, and 120 gallons. The relatively large size of these components makes precise sizing unnecessary for residential systems because of the few component sizes offered—and the accuracy of the load sizing. For large systems, since the component sizes are *relatively* smaller, more accurate sizing calculations are prudent.

Load Sizing

SHW systems are designed with a recovery time of one day—i.e., the storage tank capacity equals the estimated daily usage. How much hot water does your family use each day? Don't know? Count yourself along with 99% of people in the United States. Since hot water is not separately metered, almost no one knows how much they use with any degree of accuracy. Grid-connected PV system designers have easy, accurate loads to work from—better known as the electricity bill. But the best estimate in the solar hot water industry is just a guess. Carl Bickford's article ("Sizing Solar Hot Water Systems" in *HP118*) gives some good estimates for households of four—15 gallons per person, per day for conservation-minded families, and double that for a typical family. The article also gives you information on how to closely measure your family's usage if you care to take a 5-gallon bucket and a stopwatch into the shower.

Government Guidance

The DOE consumer guide, "Heat Your Water with the Sun," advises contractors to allow "about 20 square feet of collector area for each of the first two household members and, for each additional person, either 8 square feet (for those in the Sunbelt region) or between 12 and 14 square feet (for those in more northerly climes). (See www.nrel.gov/docs/fy04osti/34279.pdf for more information.)

Solar Hot Water Collector Sizing

Location (Sun-Hours)	Water Heated Per Day (Gal.)	Multiplier*	Collector Area (Sq. Ft.)	Collectors Needed
Most of the U.S. (up to 5 sun-hours per day)	80	0.67	54	Two 4' x 8' **
	120	0.67	80	Two 4' x 10'
Sunbelt (5 or more sun-hours per day)	80	0.50	40	One 4' x 10'
	120	0.50	60	Two 4' x 8'

*The multipliers can be used for any size of tank—a 66-gallon tank in most of the United States would need 44 square feet (66 x 0.67) of collector area or two 3' x 8' collectors. In the Sunbelt, a 66-gallon tank would be sized along with a single 4 x 8 collector.

**A system for a conservation-minded household would be more accurately designed with two 3' x 8' or two 4' x 6' collectors for an 80-gallon tank.

For active (pumped) systems, the solar storage tank size increases with the collector's size—the ratio they suggest using is 1.5 gallons of storage capacity per 1 square foot of collector area. A 66-gallon system can accommodate one to three people; an 80-gallon system works well for a three- or four-person household; and a 120-gallon system is well-suited for four to six people.

Here's the math behind those recommendations: A typical household of four needs 64 square feet (20 + 20 + 12 + 12) of collector surface area to heat their water. Using the ratio of 1.5:1 would translate to needing a storage tank capacity of 96 gallons (64 square feet × 1.5 gallons per square foot). However, manufacturers don't make a 96-gallon tank; the closest size is 80 gallons.

In the Sunbelt, the same family needs 56 square feet (20 + 20 + 8 + 8) of collector surface area to heat their water and an 84-gallon storage tank (56 × 1.5). Again, the closest size of tank available is 80 gallons.

A little division gives us an average of 20 gallons a day per person, per day for the typical family. This could be high or low depending on how efficiency-minded a household is, but the examples of storage tank sizes to family members is a good guesstimate.

Simple & Quick

A simple method that installers have been using for decades starts with estimated tank sizes based on that per-person average of 20 gallons a day. In most locations in the United States, 1 square foot of collector surface area will heat 1.5 gallons of water daily. In the Sunbelt, 1 square foot will heat 2 gallons. Using this method, The multiplier to arrive at estimated collector surface area when the water volume is known (guesstimated) is 0.5 in the Sunbelt (more than 5 daily sun-hours) and 0.67 for the rest of the United States. Sun-hour averages range from 3.7 sun-hours in Seattle to more than 6 in Sunbelt areas.

Keep in mind that load sizing is almost always an educated guess. Plus, sun-hours vary. Shading and system efficiency can also affect performance and may be reasons to increase collector area. The local climate also affects production, with mild climates producing more hot water compared to cold climates with the same average sun-hour values. Average daily sun-hours can be found for more than 200 locations in the United States at http://rredc.nrel.gov/solar/pubs/redbook/. The units given in the Redbook are in kWh per meter squared per day, commonly known as daily sun-hours.

Look It Up

The SRCC publishes system performance estimates based on OG-300 data computed with local solar resource data from the Redbook. The database allows users to choose from more than 100 locations in the United States, and also choose the manufacturer of the system they want to learn about. The results are listed in a column called Energy Saved. This value is given in kWh per year for systems designated by the manufacturer to have an electric backup water heater and in therms saved per year for systems with gas backup. Many state, municipal, and utility incentive programs use this database of estimated savings to compute their rebates. (To access this database, click on the Annual Performance of OG-300 Systems link at www.solar-rating.org/ratings/ratings.htm.)

The OG-300 system isn't a sizing system per se, and installers will normally use another method of sizing. But in locations where operating guidelines are used for incentive calculations, the lookup defines what systems are used. OG-300 systems specify a certain size of collector(s) that are incorporated with a certain size of tank, and the system designer has little or no leeway to deviate from the published specifications, although there are hundreds of choices in the OG-300 listings. Note that in most places in the United States, the requirement for OG-300 certification is the exception, not the rule.

More Accuracy

Carl's SHW sizing article has good instructions for more accurate collector sizing in addition to estimating a home's water heating loads. But if longhand math doesn't strike your fancy, there are a few commercial SHW sizing systems on the market. First is the deep, but free, RETScreen (www.retscreen.net). A 44 MB download with a steep learning curve, RETScreen does almost everything but make coffee. Two other commercial solar hot water sizing software programs are Polysun and T*Sol. The thermal software that comes with the Solar Pathfinder site survey tool also has a built-in basic sizing program.

But, for one last time—sizing and design of small residential solar systems almost always starts with a guess that we call load sizing. Getting nerdy with precise calculations for small systems might seem like a good idea if you are sure of the load, but the relative size of the components will still limit the choices of system sizing and most often render the accuracy moot. Does sizing small SHW systems fit better into art or science—or perhaps gambling—sometimes?

—Chuck Marken

Lone Star Solar

A recent issue of *Home Power* has passed around our office to land upon my desk. Like most Texans, the thought of solar power or alternative fuels to lessen our carbon footprint seems not needed. We have plenty of oil that keeps Texas very independent.

Having said that, I now feel that Texas may have fallen behind from the rest of the solar generation. We are just now actively seeking more information. Most of us out here are ranch owners needing wind, solar, and even hydro power.

Lee Cherry • Huntsville, Texas

Home em*Power*ment

I just bought my one-year subscription of *Home Power* and am looking forward to introducing some senior high school students to it also.

All in all, I just found you all today and I am quite happy with so much wonderful information both in the subscription magazine and on Facebook. I'm very interested in turning our home—and helping our neighbors turn their homes—into more efficient and more self-sustaining buildings. What a great idea that was neighbors helping neighbors ("Greening the Neighborhood" in *HP134*)!

Lauralee Freedom Conklin • via Facebook

Fighting for Efficiency

I live off-grid with solar and a backup generator. I use an inverter when necessary and I haven't found it necessary or efficient for lighting. I've used DC lights for years and have finally converted to all 12 V LEDs.

I'm very pleased with the way things are, but for my frustration with manufacturers and suppliers, who seem to think we all want nothing more than to plug all devices into AC wall sockets.

Not only is it stupid to use 120 VAC to run DC devices (most electronics), but it's inefficient as well. I'll not fight that battle other than to disconnect phantom loads, but I refuse to switch to AC for lighting.

The problem is, no one seems to be making DC household switches, and I've been told that AC switches (rated as "AC only") can start a fire when used with DC. I've never had a problem, but I do worry about the possibility.

I've been a loyal subscriber from day one, and can't imagine being without *Home Power* magazine. Keep up the good work and don't forget about us non-grid-tied folks. We're a minority who, more than ever, needs a voice.

Bob La Fleur • Ponsford, Minnesota

Blackouts & Battery Backup

People for the most part do not understand the prohibitively expensive nature of "whole-home" battery backup—or even battery backup in general if they are grid-tied users.

I got loads of questions about this when I was designing systems. In the end, no one ever wanted to pay for the additional inverter, batteries, automatic transfer switches, extra subpanel, etc.

I imagine that whole-house battery backup with an AC-coupled system is a solution for a problem that less than 2% of Americans experience. There's a break-even point where it just makes sense to have a small natural gas or propane generator for the percentage of time you have longer blackout situations.

Pamela Cargill • via Facebook

From Rails to Road

As a retired railroad mechanic, I read with interest the story on the Chevy Volt in issue *HP140* ("Getting Charged with Chevy's Volt").

General Motors (GM), through its electromotive division (EMD), has been making some of the finest locomotives out there for many decades.

Some of your readers may be surprised to know that the diesel engines in locomotives don't directly power the wheels. The engine turns, among other things, a generator that sends current to traction motors mounted on each axle. These motors are also used for braking (called dynamic brakes).

Locomotives were also one of the first to use antilock brakes. When you lock up steel wheels on a steel rail, the wheels can get so hot they can start to melt. This is like grease on the rails, and the train will actually speed up.

With GM's long track record of top-notch locomotives, I am sure the Volt will be one of the best cars, as long as politics can be kept out of it.

Howard Anderson • Ash Fork, Arizona

Think Twice About Your Rural Paradise

In response to a reader asking what he should look for when he's buying property ("Ask the Experts" in *HP142*): You can minimize your footprint anywhere.

Often times, the more rural and secluded you are, the more you may be reliant on your car or truck rather than public transportation—and the distances you need to travel [to get to services] are much greater.

With us, having always lived and worked here on our place, it's not that much of a problem, but anyone who relies on an outside job for income may find that their rural paradise becomes a bedroom that is visited.

Bruce Brummit • via Facebook

Errata

The schematic in "Renewable Energy Healthcare in Haiti" (*HP142*) should have shown the "no-generator-contact" inverter connected to the battery bank, rather than to the charge controllers. See the corrected schematic online at www.homepower.com/webextras.

write to:

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Classic MPPT Charge Controller
Comparison Chart

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- Our setup Wizard walks you through all the steps necessary to tailor your unique system.
- Did we mention American Made! American Quality! American Jobs!

CLASSIC MPPT CHARGE CONTROLLER COMPARISON CHART

Manufacturer	MidNite	OutBack		Blue Sky	Xantrex	Morningstar	Apollo
Model	[1] Classic 150	FM60	FM80	3048DL	XWMPPT60	TSMPPT60	TS80
Rated Amps	80 - 96	60	80	30	60	60	80
Max Operating Voltage	150	145	145	112	140	150	112
Max VOC	[2] 162, 175, 200	150	150	140	150	150	200
Max Battery Voltage	72	60	60	48	60	72	48
Solar	●	●	●	●	●	●	●
Wind	●						
Hydro	●	●	●				
List Price With Display	$850	$749	$849	$649	$685	$793	$849
Cost Per Amp With Display	$10.63	$12.48	$10.61	$21.63	$11.42	$13.22	$10.61
Digital Display	●	●	●	●	●	Option	●
Internet Ready	●	$595 Option				●	$398 Option
Ground Fault Detector	●				●		
Arc Fault Detector	●						
Wizard Setup	●						
Graphical Display	●						
Free User Upgradeable Firmware	●					●	
Multiple Display Support	[3] MNGP	[4] MATE	[4] MATE	SB50RD25	XW-SCP	TS-RM-2	[5] RD-Wired
Aux Output	2	1	1		1		2
Aux Input	1						
Sealed Or Vented Configurable	●						
Warranty (Years)	5	5	5	5	5	5	5
Oscilloscope Display	●						
Battery Status Meter							●
Substantually Made In USA	●	?	?	?			
Voice	●						
Partial Shading Indicator	●						
Sunrise/Sunset Map Of World	●						
Bonus Amps Based On Voltage	●						
ModBus Communications	●				●	●	
External Shunt Input				●			
HyperVOC Extended VOC Limit	●						

1 The Classic comes in four models, 150, 200, 250, and 250KS
2 This number is based on the max operating voltage of the unit plus nominal battery voltage.
3 The Classic MNGP display and/or a secondary display can monitor many controllers. The MNGP display can be removed from the Classic and used remotely.
4 If more than one controller is used you must also add a hub 4 or hub 10.
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DELTA


Courtesy David Emrich

Sizing Inverters for Cloud-Edge Enhancement

The other day, I glanced at my PV system's wireless monitor and was quite surprised to see an unusually high power reading of 2.75 kW AC. My grid-tied system (12 Sharp 208 W modules and an SMA America SB3000 inverter) has an STC rating of 2.49 kW DC. It typically only produces a high reading between 2.1 and 2.2 kW AC. The power surge, which happened on a partially cloudy day, was likely from an "edge-of-cloud" effect, which occurs when the sun is coming out from behind clouds. Having both direct sunlight and light reflection off the clouds causes more sunlight on the PV modules—and a brief increase in amperage.

When sizing the PV system components and wiring, designers try to account for the highest possible voltage and current. But I have never come across any adjustments in the calculations to account for the edge-of-cloud effects. As a matter of fact, none of the PV books I've read even mention this effect. It seems to me that however briefly the phenomenon lasts, the higher solar irradiance of the edge-of-cloud effect produces a significant increase in amperage (and only a slight increase in voltage) that should be taken into account. What do you think?

Marc Fontana • via e-mail

Your observation of cloud-edge enhancement is correct. It is possible to get 20% to 30% higher irradiance than the "peak" of 1,000 watts per square meter during one of these events. The physical phenomenon is the refraction of light with cumulus clouds. Light near the edge of the cloud is bent and dumped around the perimeter of the cloud. If you happen to be flying on a day with cumulus clouds, observe the shadows on the ground. You will see a bright band of light around the edge of the shadow. This is not an optical illusion—and it's more irradiance that a PV system can use.

Historically, PV designers have not worried about capturing this extra power since the amount of energy in these spikes is quite small. (In Santa Clara, California, for example, it's most likely less than 0.25% of annual energy.) The reason for dismissing this extra performance was that inverters used to be twice as expensive. However, with the declining costs of inverters, it is now more cost-effective to oversize an inverter and capture these events. Oversizing also has other benefits, such as a cooler-running and longer-lived inverter.

The caution for those new to solar electricity is that when you oversize the inverter, don't expect a lot more power or energy. A 2,500-watt STC array with a 3,000-watt inverter will rarely see more than 2,000 watts at noon on a sunny day. However, the cloud-edge power spikes will be captured, so you can feel good about the fact that you bought a little more inverter than you actually needed.

In summary, sizing for cloud-edge effects makes good performance and reliability sense, although it will cost you. By sizing an inverter 10% to 25% larger than your modules' STC rating, the inverter will run cooler, last longer, and capture the energy in those short bursts of extra power. Inverter sizes are often given in ratios of STC module rating to inverter capacity. Conventional wisdom is to size a PV array to 110% or 120% of inverter capacity. This means a 4,800 W STC array would be well-sized for a 4,000 W inverter. However, in locations that get a lot of partly cloudy weather, a 5,200 W to 6,000 W inverter will better capture those peak times and run cooler the rest of the time. However, in this example, the cost premium would be in the $500 to $800 range, and may not provide a return on the investment over time. (For more information on the edge-of-cloud effect, see "Back Page Basics" in *HP142*.)

Bill Brooks • Brooks Engineering

Module Temperature Coefficients

Sometimes, manufacturers list open-circuit voltage temperature coefficient as a percentage per °C, and sometimes as mV per °C. How do I change one to the other for comparison? Could you give me an example? For instance, what would be the Voc at -10°C?

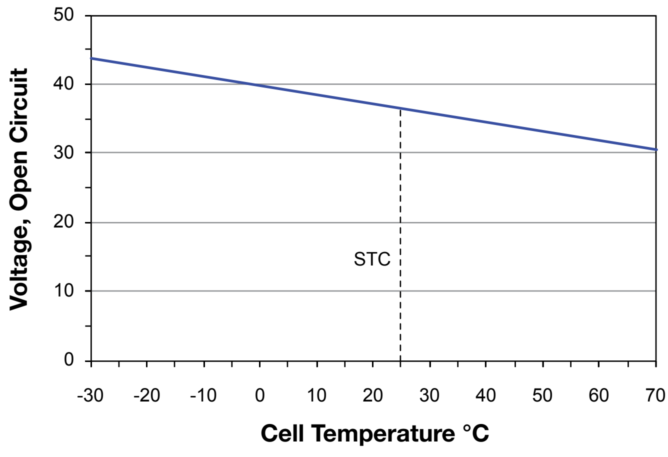
Brandon Willard • via e-mail

The voltage of a PV module varies inversely with the temperature of the cells. Voltage increases when temperature decreases; voltage decreases when temperature increases.

Manufacturers' temperature coefficients are used to find module voltages for cell temperatures that differ from the standard test condition (STC) temperature of 25°C. In the field, cell temperatures can vary from 80°C to -40°C, so module voltage can vary significantly from the voltage specification depending on the climate.

Since voltage has an inverse relationship to temperature, the coefficient is always a negative number. If the temperature coefficient is given in % per °C, convert this to volts per °C by multiplying the module open-circuit voltage by the given coefficient and dividing by

Inverse Relationship Between Temp & Voc



100 (see example below). If the coefficient is given in mV, change this to volts by dividing by 1,000 (since there are 1,000 mV in 1 volt).

Once the coefficient is in volts per °C, adjust the module's open-circuit voltage based on the change in cell temperature compared to the STC temperature. Following is an example using -10°C as the cell temperature for a module that has an open-circuit voltage of 36.6 and a temperature coefficient of -0.36% per °C. You can apply the same procedure to your module's specs.

First, convert the % per °C to voltage per °C by multiplying module open-circuit voltage times the temperature coefficient, then divide by 100. In this example: (36.6 V × -0.36/°C) ÷ 100 = -0.132 V/°C. This means for every degree change from STC, the module's voltage will change -0.132 V (or -132 mV).

Next, calculate the module voltage at this temperature (-10°C) using the following formula:

Module Voltage = Voc + {(Tcell – TSTC) × (Tcoef Voc)}
= 36.6 V + {(-10°C - 25°C) × -0.132 V/°C}
= 36.6 V + {-35°C × -0.132 V/°C}
= 36.6 V + 4.62 V
= 41.22 Voc

This result means the module's open-circuit voltage will be 41.22 if the cell temperature is -10°C. The cells' temperature is 35°C lower than STC temperatures, so the voltage is higher.

National Electrical Code (NEC) Sections 690.7 and 690.53 require that maximum system voltage be calculated using the lowest expected ambient temperature at your location. This voltage is one part of the DC system characteristics label required by the *NEC* for all PV systems.

Temperature coefficients refer to *cell* temperature, not ambient temperature. The cells of a module are generally the coldest in the early morning, just as the sun is rising. At this time, the cell temperature is essentially the same as the ambient temperature. This means we can use the coldest ambient temperature where the system is installed as the cell temperature to calculate the module's maximum voltage.

If you have a string of these modules, then each module in the string has a voltage of 41.22. The open-circuit voltage at the inverter is the sum of all the adjusted module voltages in the string. Since inverters must operate within their voltage range specification, this adjusted voltage could affect the number of modules in a string, depending on the temperatures where you are installing the solar-electric system.

Brad Burkhartzmeyer • Sun's Eye Solar Power

Battery Rescue

My off-grid friends have a rag-tag set of modules that develop 17 amps, maximum, and a bank of eight T-105 batteries (wired for 12 V nominal), which are only a year old. The charge controller is an RV Solar Boost 50. The batteries have never been equalized, and are exhibiting signs of sulfation—they charge and discharge rapidly. My friends don't take the batteries much below 12.25 V. If it's sunny, the batteries are fully charged before noon. One day's use take them down to about 12.3 V. When the charge controller says they're fully charged, hydrometer readings indicate only a "fair" reading, with three or four cells reading in the discharged zone. The usage has been higher lately due to the couple's retirement, so the rapid discharge wasn't in itself alarming. But the hydrometer readings were a red flag.

For equalizing, they have a Trace inverter/charger and a 3,500-watt, 120 VAC Sears generator. It doesn't have a 240 VAC circuit. According to my reading in *Home Power* and the inverter manual, the estimated 15 A from the charger won't really equalize the batteries. However, when the inverter is switched to equalize, the voltage will rise to above 15.6 V. They currently don't have a meter to read the battery charger's output amps.

The batteries have been brought up to full charge with the generator when experiencing successive cloudy days. Should we attempt to equalize with what we have? Is it better than nothing, or just a waste of gas? We would have tried a generator session, but are working on improving the battery box ventilation as we were getting quite a strong smell when attempting an extended run. The voltage was pushing 16 V after only an hour.

Would a desulfator be helpful? There is very little mention of them in *Home Power* and solar businesses don't appear to sell them. What is the desulfator story? There are many offered online, but again, not from photovoltaic companies!

The battery cables are clean; the batteries and their terminals are clean. Electrolyte is checked regularly. The system could benefit

Courtesy Trojan Battery

from more modules and batteries, I think, but in the meantime, what can be done? Can their batteries be rescued with what they have?

Murray Eaton • Gold Hill, Colorado

You can try a battery-rescue mission with what you have. Using the generator would only be a waste of gas if the battery cases are cracked or the positive terminals are bulging the plastic on top. No doubt I'm preaching to the choir here, but there is *no* substitute for regular and proper battery maintenance, including equalization!

First of all, give the batteries a once-over, being sure to wear, at a minimum, safety glasses and rubber gloves anytime you are working on the bank. Remove any corrosion from the battery terminals with a wire brush. Insulate your wrench handles if you have to remove wires from the terminals, then clean and reconnect them. Next, clean the battery tops with a wet rag, being careful not to spill liquid into the cap vents. Then, check every connection to every battery terminal and tighten them as needed. If your hydrometer is not temperature-compensated, you should purchase one with an integrated thermometer.

Charge the battery bank until it reaches "float" condition, and top off each cell to the mark with distilled water. Next, measure and write down the specific gravity of every cell. Now it's time to start the equalization cycle. According to Trojan Battery, your 15 A of charging current from the generator is more than ample to equalize that particular battery bank; they recommend between 9 and 27 A.

After a full equalization cycle, rest (or use) the battery bank for a day or two, charge it up to float again, top off the cells, and measure and record the specific gravity (SG) from each cell. Did anything change? If the SG is higher compared to your first reading, or there is less difference between the readings of different cells, it's possible you are making some progress! Trojan Battery recommends equalization for that particular battery bank when full-charge SG falls below 1.25, or if there is a difference of more than 0.030 between cells. It would be well worth investing in a bit more gas to try the procedure above a few more times. If nothing is changing the SG readings, the batteries are probably ready for a trip to the local battery recycling center.

As for battery desulfators, both chemical and electronic, I've been reading anecdotal reports about them for more than a decade, but have run across no trusted empirical data. Part of the problem is that every battery is different, and can be damaged in different ways. Some experts also point out that any modern PWM or MPPT solar charge controller is doing something very similar (but more gentle) to the batteries, acting as an electronic desulfator and giving them a series of pulses instead of steady current.

Trojan Battery told me that they do not recommend the use of either electronic or chemical desulfators. They point out that these are both indiscriminate, attacking all the

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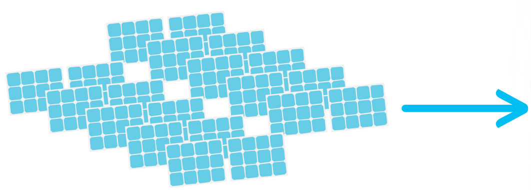

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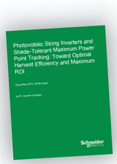

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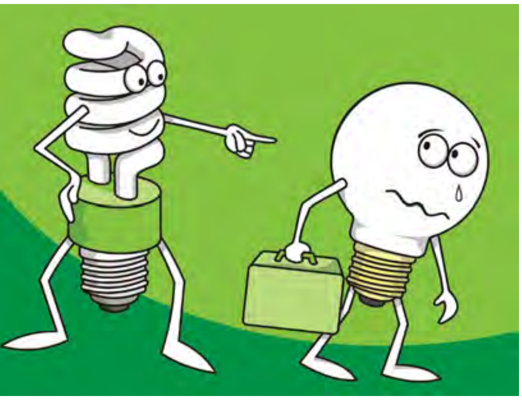
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battery plates, both positive and negative—not just the lead sulfate—thus reducing battery life. The use of any sort of desulfator will void your Trojan Battery warranty. Good luck with your rescue mission!

Dan Fink • Buckville Energy Consulting

Solar-Electric Newbie

I am trying to install solar power at an off-grid cabin, but I'm new to solar electricity, and am struggling to understand how much usable energy a PV module can provide. For instance, how long could I run a 100 W lightbulb with the electricity generated by a 45-watt solar-electric module?

Kim Showalter • via e-mail

This is a big topic—one which is covered in days in online and in-person workshops, and in many *Home Power* articles. So I'll only give you the big picture overview here.

Stand-alone system design has several steps:

1. Load analysis: Determine how many kilowatt-hours (kWh) you need per day.
2. Reduce your usage via energy efficiency and conservation.
3. Determine your solar resource—measured in average peak sun-hours (a measured value that might better be called "full sun-hours" or "perfect sun-hours").
4. Determine your solar-electric capacity with a formula like: *kWh ÷ peak sun-hours ÷ factor*. The factor for an off-grid battery-based system might be 0.65, so one example might look like this: 600 Wh per day ÷ 3.5 peak sun-hours ÷ 0.65 = 264 rated watts of solar-electric capacity.
5. Base your battery bank size on how many days without sun you are willing to live with, and specify other components.

In your example, a 45-watt rated PV module will produce roughly 120 watt-hours per day if you have 4 peak sun-hours (45 W × 4 sun-hours × 0.65). This means that you could run a 100-watt lightbulb for 1.2 hours per day if you have 4 hours of sunshine each day.

That brings us back to Step 2: Ditch the 100-watt lightbulbs, and instead use energy-efficient compact fluorescent lightbulbs (CFLs) or light-emitting diodes (LEDs). With a 25-watt CFL, you will get the same amount of light as a 100-watt incandescent bulb, but with a quarter of the energy use. This means the same PV system could run the bulb for 4.8 hours per day.

Ian Woofenden • *Home Power* Senior Editor

write to:

asktheexperts@homepower.com

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Outside Positive Plates (OSP™) = More Amp Hours.

The primary causes of positive plate deterioration are positive grid corrosion and positive active material wear-out or softening and shedding. These failure modes are the result of the normal overcharge required to fully charge batteries and to mix the electrolyte to prevent electrolyte stratification. In addition, batteries that are used in applications that require continuous float charging may be more susceptible to grid corrosion as a result of prolonged overcharging. Also, batteries that are subjected to frequent deep discharges (greater than 50% DOD) often exhibit increased effects from positive active material wear-out. This is usually the case in Renewable Energy applications. Testing at U.S.Battery has shown that an effective method for mitigating the effects of positive plate deterioration is to increase the ratio of positive to negative active material by ***adding a positive plate*** and removing a negative plate from a conventional cell design resulting in an Outside Positive (OSP™) cell design vs a conventional Outside Negative (OSN) cell design. This design approach results in a cell with increased positive to negative active material ratio, increased positive to negative grid ratio, and increased protection of the positive plate from positive plate deterioration. This results in longer life, increased capacity, and more stable performance over the life of the battery.

The only battery in its class with DEFENDER™ Moss Shields for longer reliable battery life.

Electrical shorting can be caused by 'mossing' shorts at the top of the cell element. These mossing shorts are the result of positive active material particles that have softened and shed from the positive plates, become suspended in the electrolyte, and eventually collect at the top of the cell element. Once enough of this material has collected to bridge the tops of the separators, it can contact both a positive and a negative plate where it converts to conductive lead and forms a short circuit resulting in cell and battery failure. This failure mode is more prevalent in stationary applications than in vehicular applications because of the absence of vibration and shock that normally dislodges the mossing material and causes it to fall to the bottom of the container where it collects innocuously in the mud cells. Testing at US Battery has shown that the use of insulating 'moss shields' in batteries used in these stationary applications can effectively prevent the formation of these mossing shorts. This results in longer life, increased capacity, and more stable performance over the life of the battery.

SPECIFICATIONS RE L16 / 6-VOLT

AMP HOURS (100hr.rate)	441
AMP HOURS (20hr.rate)	401
AMP HOURS (5hr.rate)	332
MINUTES (@ 75 AMPS)	245
MINUTES (@ 25 AMPS)	915
LENGTH	11-7/8" (302mm)
WIDTH	7-1/8" (181mm)
HEIGHT	16-3/4" (425mm)

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Is Wind Electricity *Right* for You?

by Ian Woofenden
& Mick Sagrillo

Shawn Schreiner

Vince Culp of Energy Unlimited gets ready to raise an Endurance S-343 on a 90-foot hydraulic tilt-up tower.

Wind electricity is an enticing technology, drawing attention to itself with every turn of the blade. But for the uneducated consumer, wind power can end up being the most disappointing of RE technologies. This is not because it's a hopeless endeavor to capture the energy in the wind, but because it's a difficult job. Unfortunately, the technology also seems to attract more backyard "inventors" and hucksters than other renewable technologies.

Before you are hired for a new job or are accepted as a new student, you need to pass interviews, tests, and other evaluations. Perhaps wind electricity consumers should put themselves through a similar grilling before taking on the job of wind-electric system owner. In this article, we'll run you through some tests to see if you qualify.

Site Evaluation

One early step is to look at your physical site. Productive wind-electric systems take *space.* If you live in a city lot, an apartment, or even on a small suburban lot, installing a wind-electric system may be difficult or impossible. Even if you have the space, most urban settings have little, if any, wind resource.

Freestanding towers can have a very small footprint, and in fact can be installed on very small lots. Fixed guyed and tilt-up towers both need a more substantial footprint, for the guy wires and for tilting down. These are often not options on small lots.

Successful wind-electric systems need tall towers that put the wind generator in the smooth, strong wind, well above obstructions. This can be very difficult on small lots, and may also lead to objections by neighbors and others.

The hard reality is that in today's cultural and legal climate, small wind systems are primarily successful as a rural technology. If you don't have an acre or more of ground, you'll have an uphill battle to permit and install a system that generates the electricity expected from it.

Legal Limitations

In addition to space and neighbor constraints, you'll often face legal hurdles, especially in the city and suburbs. Objections to wind energy systems come with their own ignorance, fear, and misconceptions. Unfortunately, local officials are sometimes ill-informed and may give too much credence to fear-mongering or antiwind zealots.

It's common to find local or state statutes that restrict tower height to 30 to 60 feet—heights that hamstring a system to poor performance. These sorts of limits need to be challenged in administrative offices and courtrooms. Better yet, do the necessary education and change the permitting language proactively to avoid battles later on. Bowing to ordinances that limit tower height only results in poorly performing systems, and sets a bad precedent.

Courtesy Endurance Wind Power

Tilt-up towers require a large, open site to raise and lower the tower, but guyed towers can be sited on cluttered sites and even between buildings.

Power Available & Wind Speed

% of Rated Wind Speed	Wind Speed (mph)	% of Power Available
100.00%	24.0	100.00%
50.00%	12.0	12.50%
25.00%	6.0	1.60%
12.50%	3.0	0.20%
6.25%	1.5	0.02%

Laws that require a distance between your tower and buildings or property lines are called "setbacks," and they can set your project back—in dollars and productivity. These restrictions vary by jurisdiction; we wonder why utility poles and towers are allowed close to roads, homes, and schools, while similarly engineered wind generator towers typically are not. Tower failures are rare, and real-world results show that, in the unlikely event that a failure occurs, the tower tends to buckle, instead of falling to its full height. Correcting unreasonable setbacks will make your project more functional, and help the industry mature.

Local jurisdictions may suggest or even require that you get comments or consent from neighbors before you are granted a building permit for your wind-electric project. Such requirements rarely, if ever, are enacted for other building or construction projects, and wind systems should not be treated any differently. Community pressure can change ill-conceived regulations. Meanwhile, we suggest that you become friendly with your neighbors, share your renewable energy passion, and get them on your side before it becomes a legal issue.

Resource Assessment

If you have the space and can deal with the bureaucracy, a next step is to find out what sort of wind resource you have. "It's always windy here" is not a scientific observation, and it's also rarely true. Wind is the fuel, and finding out its strength and quality will be crucial to your wind-electric system's performance.

What you want to find is an *average wind speed.* This is not a guess, not a peak gust, not an observation, but a measured or extrapolated *average* of the winds on your site over the years. At home sites where the turbine sits on a tall tower, a realistic average is between 6 and 14 mph. However, a 6 mph average wind speed site is not ideal for on-grid systems, and is marginal at best for off-grid ones. A site with an average wind speed of 14 mph will give high production (and will require robust equipment), but is rare where most people live. While there are certainly exceptions, average wind speeds of 10 to 12 mph at tower-top height are typical at rural home sites.

Determining the average wind speed on your site is not always easy. You may be able to do short-term monitoring with anemometry and correlate with nearby data, but this is difficult to do without proper training and experience. More likely, you'll lean on a professional site assessment or wind mapping data. Don't grab map data and take it at face value, though. Most trained site assessors have learned what data they can trust, and know how to derate or adjust the mapping data to determine real-world conditions in your area.

With an estimate of your average annual wind speed at hub height (the wind generator's rotor center), you can look at production estimates from manufacturers (see the wind turbines table on pages 56–59). Then you'll have a rough idea of what you can expect in annual energy production (kilowatt-hours; kWh) from your system, and compare it to your energy use. In this way, you'll be realistic about what portion of your energy consumption and utility bill the system will offset.

Tower Economics

Once it has been determined that a good resource exists, the most common mistake for small wind systems is putting a wind generator on too short of a tower. This is akin to putting a solar collector in the shade. Wind power is a cubic resource—doubling its speed increases the power available to the system eight times. So going a little higher to get into faster wind speeds can reap large rewards.

Since most people don't live in a perpetual "tornado alley," where winds are constant and high, another way to think of this is in reverse—what happens when wind speeds are cut in half, or even more? The "Power Available & Wind Speed" table gives you an idea of how much power is available in winds *below* the rated wind speed (often about 24 mph) of most well-designed wind turbines.

Inset: A wind turbine on a short tower is a waste of money if your goal is to produce energy.

Main: To recoup your investment, wind turbines should be sited far from, and well above, any obstructions to the wind.

Courtesy Ian Woofenden (2)

Turbine Choices

Choosing your wind turbine is, first of all, a match between your electricity loads—how many kWh per year you use—and the prediction of what your system's production will be—also in kWh per year—based on the average wind speed at your site. Scan the table across the row for average wind speed, to see which of the turbines listed can meet your needs.

In addition to predicted energy output, you should consider the turbine's durability, which is harder to gauge. Heavier-built turbines will tend to stand up better in rough storm conditions. Within a particular size range, more expensive turbines may also fare better. Turbines with longer warranties perhaps will last longer, or at least you'll have recourse if there are problems.

This year, the first "certified" turbines will be available in the United States. As of mid-April, the Small Wind Certification Council (SWCC; www.smallwindcertification.org) had applications from 21 companies for 25 different turbine models. By the end of the year, some turbines will receive their certification with verified testing of energy production. This is an exciting development in the industry, which has been troubled for years by misleading marketing claims.

Turbine Size

"There's no replacement for displacement" is a common phrase in the engine world. "Swept area matters" is the analogous statement in small wind circles. The "rotor"—the blades and hub, which sweep a circle measured in square feet—is the collector area. More collector means more wind energy collection. Ignore advertising claims that you can get lots and lots of energy out of a small collector. They're just not true.

If you don't have verified production numbers for the turbine, swept area is as good of a comparative measure as we have to guess at wind turbine production. In general, home-scale turbines fall within the 12- to 50-foot-diameter range if your goal is to meet a significant portion of your home's energy needs.

(continued on page 60)

Courtesy Bergey Windpower

Although smaller turbines are manufactured, the Bergey XL.1 is the smallest in our survey of residential-scale turbines.

What's in the Table?

The table on pages 56 through 59 shows basic specifications for small wind turbines available and supported in North America. Understanding the specs will help you make intelligent turbine-buying choices.

The *manufacturer* indicates the source of the wind turbines listed, either manufactured in North America or imported.

Swept area is the area in square feet of the rotor. This is the "wind collector" area, and besides average wind speed, is the biggest factor influencing turbine output. A larger rotor will capture more energy.

Warranty is noted in years, but we urge you to find out what is covered and what is not. Usually it only covers the equipment, not the replacement labor costs and shipping, which can be significant. Several manufacturers also offer extended warranties for an additional cost.

SWCC status refers to the Small Wind Certification Council (SWCC), an independent certification body, which certifies that small wind turbines meet or exceed the requirements of the AWEA Small Wind Turbine Performance and Safety Standard. This certification provides a common North American standard for reporting turbine energy and sound-level performance. The table notes whether the manufacturer has applied for certification with the SWCC, but not the status of the application or how far along the testing is. Turbine certification will likely be required to qualify for some states' financial incentives. Since these agencies typically fund only grid-tied systems, manufacturers are unlikely to apply for certification for off-grid systems, which are usually the "smaller" small turbines.

While only a handful of manufacturers are in the process of *SWCC* certification, other companies may be pursuing certification from other agencies. For example, there are several certification bodies in Europe, and many of the turbines listed are manufactured there. In addition, other organizations in other parts of the world offer various types of certification for turbines or turbine components. However, since public benefits programs will likely rely on SWCC certification, this is the certification status to keep an eye on.

Predicted annual energy output (AEO) at hub height at average wind speed shows manufacturers' projected production for that turbine at wind speeds from 8 through 14 mph. These present some general numbers to match to your site's average wind speed and your energy needs. All of the AEOs provided in the table were supplied by the manufacturers. Your turbine's performance on your site may vary, sometimes significantly. You may want to derate the listed AEOs by about 25%. We have no evidence that all manufacturer AEOs are overstated, although some seem to be. It is certainly better to underpredict AEO, and be pleasantly surprised, than to overpredict and be disappointed.

For *installer evaluations* of the manufacturers and their equipment, 65 installers who are active and earning a living in the small wind industry were sent surveys. Using an "A to F" convention, installers were asked to "grade" the turbines and the level of service that the manufacturers provide. The table includes the average of their responses to questions, which included:

- Manufacturer's pre-sales response to product questions
- Overall quality of the product
- Completeness of order
- Post-sales technical support
- Reliability of system

We also asked installers to answer "Yes" or "No" to the following questions:

- Would you sell or install this turbine to another customer?
- Would you buy and install this turbine for yourself?


XL.1


Raum 1.3


Proven 7

	XL.1	Whisper 200	1.3	e300i	Proven 7
Manufacturer	Bergey Windpower	Southwest Windpower	Raum	Kestrel	Proven Energy
Website	bergey.com	windenergy.com	raumenergy.com	kestrelwind.co.za	provenenergy.co.uk
Specs					
Swept area (sq. ft.)*	53.0	63.5	73.0	76.0	103.6
Warranty (years)*	5	5	5	5	5
SWCC certification application	No	No	No	No	No
Predicted Annual Energy Output (kWh)*					
8 mph	420	794	908	973	1,704
9 mph	610	1,121	1,110	1,315	2,438
10 mph	840	1,483	1,539	1,726	3,494
11 mph	1,110	1,865	2,004	2,131	4,417
12 mph	1,400	2,254	2,479	2,551	5,627
13 mph	1,710	2,637	2,940	2,966	6,614
14 mph	2,040	3,005	3,365	3,356	7,842
Survey of North American Wind Installers					
Number of responses	5	0	0	0	2
Turbines installed by respondents	26	0	0	0	4
Manufacturer presales response	B+				C-
Product quality	B+				B
Completeness of order	A-				B
Ease of serviceability	A-				B
Post sales tech support	A-				C-
System reliability	B+				A-
Average overall grade	B+				B-
Would you sell or install this turbine to another customer? Yes–Maybe–No	4–1–0				1–0–1
Would you buy & install this turbine for yourself? Yes–Maybe–No	3–0–2				2–0–0

*Manufacturers' data from 2010


Whisper 200


e300i


Xzeres 110

Skystream 3.7

Raum 3.5

Montana

	Xzeres 110	Skystream 3.7	e400i	3.5	Whisper 500	Montana	R9000
	Xzeres	Southwest Windpower	Kestrel	Raum	Southwest Windpower	Fortis	Evance
	xzeres.com	windenergy.com	kestrelwind.co.za	raumenergy.com	windenergy.com	fortiswind.com	evancewind.com
	110.0	113.0	135.0	135.0	176.0	211.0	246.0
	10	5	5	5	5	5	5
	No	Yes	Yes	No	No	No	Yes
	1,629	914	2,010	2,021	1,474	3,459	3,500
	2,274	1,373	2,781	3,213	2,139	4,438	5,030
	3,039	1,925	3,807	4,380	2,907	5,443	6,670
	3,894	2,594	5,050	5,811	3,749	6,444	9,012
	4,801	3,216	5,996	7,447	4,637	7,410	10,590
	5,728	3,898	7,230	8,631	5,544	8,315	12,530
	6,643	4,575	8,285	10,272	6,445	9,132	14,500
	8	5	0	0	1	0	1
	13	30	0	0	1	0	1
	B	B			B		A-
	B-	B-			C		A-
	B-	A			A		A
	C+	C			C		B
	C	C-			C		A-
	C+	C			C		A
	C+	B-			B-		A-
	1–3–4	2–1–2			0–1–0		1–0–0
	1–2–5	2–1–2			0–0–1		1–0–0

e400i

Whisper 500

R9000

	Proven 11	Scirocco	S-343	Excel-R	Excel-S
Manufacturer	Proven Energy	Eoltec	Endurance Windpower	Bergey Windpower	Bergey Windpower
URL	provenenergy.co.uk	eoltec.com	endurancewindpower.com	bergey.com	bergey.com
Specs					
Swept area (sq. ft.)*	255.6	265.0	343.0	415.0	415.0
Warranty (years)*	5	5	5	10	10
SWCC certification application	No	No	Yes	No	Yes
Predicted Annual Energy Output (kWh)*					
8 mph	2,773	3,496	5,249	3,600	5,000
9 mph	3,973	4,997	7,293	5,400	7,100
10 mph	5,752	6,746	9,498	7,500	9,600
11 mph	7,358	8,687	11,781	9,700	12,700
12 mph	9,526	10,751	14,065	12,100	15,900
13 mph	11,331	12,870	16,282	14,500	19,500
14 mph	13,606	14,983	18,375	16,800	23,300
Survey of North American Wind Installers					
Number of responses	3	3	8	1	18
Turbines installed by respondents	4	6	40	3	110
Manufacturer presales response	C+	C+	B+	B	B+
Product quality	B	A	B+	B	A-
Completeness of order	B+	B+	B+	A	A-
Ease of serviceability	C	B	B	A	B+
Post sales tech support	D+	C	A-	A	B+
System reliability	C	B	B	B	B+
Average overall grade	C+	B	B+	A-	B+
Would you sell or install this turbine to another customer?					
Yes – Maybe – No	1–0–2	1–0–2	7–0–1	1–0–0	17–1–0
Would you buy & install this turbine for yourself?					
Yes – Maybe – No	0–0–3	1–0–2	6–0–2	1–0–0	15–1–2

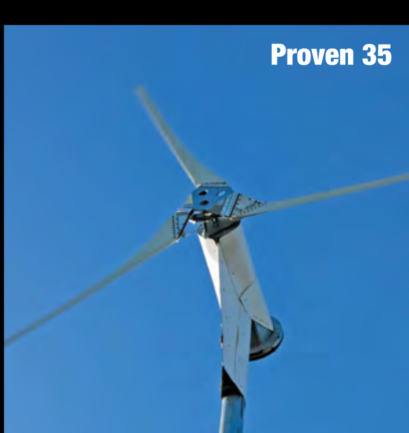
*Manufacturers' data from 2010


Xzeres 442SR


31-20


E-3120

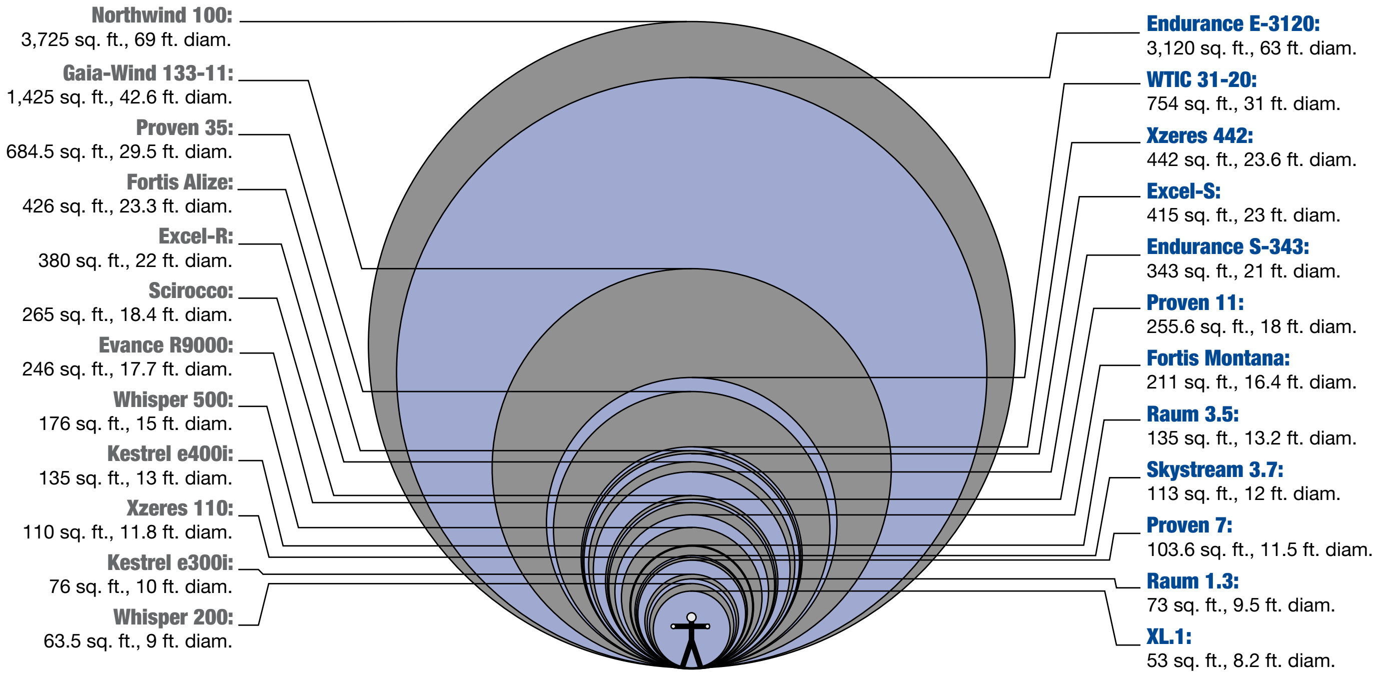
	Alize	Xzeres 442SR	Proven 35	31-20	133-11	E-3120	Northwind 100
	Fortis	Xzeres	Proven Energy	WTIC	Gaia-Wind	Endurance Windpower	Northern Power Systems
	fortiswind.com	xzeres.com	provenenergy.co.uk	windturbine.net	gaia-wind.com	endurancewindpower.com	northernpower.com
	426.0	442.0	684.5	754.0	1,425.0	3,120.0	3,725.0
	5	10	5	5	5	5	2 (5 optional)
	No	Yes	No	No	Yes	Not applicable	Not applicable
	11,098	7,081	10,759	7,295	11,535	48,145	49,099
	14,659	9,910	14,826	10,689	17,004	68,890	69,742
	18,456	13,198	20,400	14,966	22,962	91,758	98,996
	22,344	16,819	25,057	20,066	29,127	115,746	124,508
	26,156	20,628	30,895	25,836	35,263	139,955	158,135
	29,728	24,483	35,448	32,070	41,167	163,647	185,796
	32,925	28,267	40,863	38,552	48,676	186,254	220,558
	0	8	9	6	3	4	6
	0	16	18	39	4	33	20
		A-	B	B+	B+	B	A
		C+	C	B	A	B-	A
		C	C	A-	A	C+	A-
		C+	D	C+	A	B	A-
		B-	C	B-	A	B+	A-
		C	C	B	A	C+	B+
		C+	C	B	A	B-	A-
		3–1–4	2–1–6	4–1–1	3–0–0	2–1–1	6–0–0
		3–1–4	1–1–7	2–2–2	2–1–0	2–0–2	4–1–1


Proven 35


133-11


Northwind 100

Rotor Diameter & Swept Area



Maintenance

All wind generators need regular maintenance. A turbine is a dynamic piece of spinning equipment operating in a severe environment. Compare the rpm and lifetime of a wind generator with your car. Let's assume you drive your car for 200,000 miles at an average speed of 50 mph before trading it in. This equates to 4,000 hours of driving. That's all! There are 8,760 hours in a year, and your wind turbine is likely spinning and generating energy about 80% of that time, or about 7,000 hours. That's nearly two car lifetimes in a single year of turbine operation.

Well-designed wind turbines are projected to last 20 to 30 years before a complete rebuild is necessary. No one in their right mind would buy a car and expect to drive it for even 2,000 hours without inspections, service, and maintenance. Why believe otherwise about a wind turbine?

If you don't change the oil in your car, it will die an early death. If you don't maintain your wind generator, it will die an early—and probably a very dramatic—death. Turbine owners should stick with a regular schedule to keep up with maintenance.

Most required "maintenance" is centered around thorough inspections of the turbine as well as the tower. This means at least once a year (ideally twice), you need to climb or lower your tower, give it a thorough go-over, and do all necessary maintenance and repair. There's no shortcut here; no such thing as a "maintenance-free" wind turbine. As the saying goes: "If you don't pay your turbine a visit at least annually for a preventive maintenance inspection, someday, it may come down and pay you a visit." If you want a technology that doesn't require this level of maintenance, buy PV modules—they have no moving parts to maintain.

Do You Pass the Test?

So, how did you do? Ask yourself these questions:

- ☐ Do you have the space for a tower, and the type of neighbors who can live with it?
- ☐ Can you deal with (or work to change) local permitting or zoning regulations to install a productive system?
- ☐ Is there a reasonable wind resource at your site, preferably an average that falls within a 10 to 14 mph range?
- ☐ Can you afford to install a tall tower that gets your wind turbine rotor at least 30 feet above all nearby obstructions, including growing trees, for the life of the system?
- ☐ Can you afford a durable turbine that will stand up to conditions at your site for decades?
- ☐ Can you afford a large enough turbine to significantly offset your energy needs?
- ☐ Are you willing to maintain the turbine and tower or pay someone to do this on a regular basis, and are you prepared to deal the inevitable repair?

If your answer to any of these questions is "no," there are many other options for you to reach your renewable energy goals. It will be better to have a successful solar- or hydro-electric system (along with household energy-efficiency improvements) than a poorly performing or failed wind system.

If your answers are yes all the way down the list, you may be a candidate for wind electricity. Take your time, do your homework, and carefully design and install a system that will be productive and safe for the long term. There's really nothing like living with a successful wind system!

Is That "Breakthrough" Real?

Over the past few years, the media has focused attention on new small wind inventions and "technology breakthroughs," creating havoc and confusion among consumers, The hype of selling a new turbine design is often initiated in a press release that's poorly vetted by the unsuspecting or uneducated reporter. Most of these designs are marketed as being roof-mounted, and many, though not all, are vertical axis technologies.

We frequently get questions about such designs, although it is very difficult to educate a reporter or homeowner on the physics and fluid dynamics of airflow and the engineering of such designs in a few paragraphs or a short phone call. However, examining the history of small turbines can be very useful.

Vertical axis technology actually predated "modern" horizontal wind-electric turbine designs. In the 80-plus years since their invention, vertical axis turbines and most all other manner of unique rotor designs have given way to two- or three-bladed horizontal axis turbines atop tall towers. Why? Because they work, they generate electricity, and most importantly, they do so economically over many years.

The latest eye-candy gizmo that inevitably generates little energy because it sports a small collector (that is, rotor) and is sited on a rooftop or short tower where there is little to no usable fuel is soon abandoned in the marketplace. This is Darwinian economics at its best. To quote Dutch wind expert Eize de Vries, successful modern wind turbine designs have come from "evolution, not revolution."

If you insist on pursuing unusual designs that are touted as new or superior technologies, but provide little to back up their claims, make sure that you look beyond the marketing hype. Then, seek out satisfied owners—those without a vested interest in the sale—and ask them about their experiences with the turbines. Don't take it from us, but listen to the many people who have been burned and, unfortunately, soured on small wind technology because they made a poor investment choice.

Courtesy Gary Harcourt

If you (and your site) are right for wind electricity, wind electricity will be right for you.

Access

Ian Woofenden (ian.woofenden@homepower.com) teaches, writes and consults about, and uses wind energy at his home in Washington's San Juan Islands, and prefers to bicycle down–wind, because he knows wind is cubic power.

Mick Sagrillo (msagrillo@wizunwired.net) teaches and writes about, consults on, and uses wind energy, having gained his experience by installing many ill-conceived—as well as well-designed—turbines at his home in Wisconsin.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Maximize Your Mileage

by Guy Marsden

Squeeze more mileage from your hybrid car with this expert advice.

If you own a hybrid-electric vehicle (HEV or "hybrid") or are considering buying one, you've probably wondered whether these cars really get the gas mileage their manufacturers claim. Well, that all depends on how you drive it. Hybrids are quite different from standard gasoline-fueled cars, and there's a learning curve involved in optimizing their fuel economy.

My wife Rebekah and I have been driving HEVs for more than a decade. She purchased the original two-seater Honda Insight hybrid in 2001, and we immediately made a competition out of who could get the best mileage per trip. We developed several strategies for that vehicle, some of which did not translate to the 2006 Ford Escape hybrid that I purchased later. The two-seater Insight (made from 2000 to 2006) is considered a "mild hybrid"—one that never operates entirely in electric mode. For that reason, many of the strategies discussed here do not apply to that vehicle.

Most of the HEVs on the road are considered "full" hybrids—they can drive for several miles in electric vehicle (EV) mode alone. One of the keys to understanding how to optimize HEV performance is to learn how to make the best use of the battery that powers the electric motor.

Regenerative Braking

All HEVs have both an internal combustion engine (ICE) and an electric motor, which gets energy from a battery pack. In many HEVs, such as the Toyota Prius, the ICE is an Atkinson engine which, while efficient at its optimal rpm, does not develop much torque at low rpm—so it's rather inefficient during acceleration. The electric motor augments the ICE during acceleration—the faster you accelerate, the more battery power is used. Of course, most hybrids can also operate entirely in electric mode for periods and this uses a lot more battery energy.

The electric motor is used as a generator anytime you take your foot off the accelerator or apply the brakes. Additionally, once the car is up to speed and cruising along, the generator tops off the battery if it is low. This is known as a "cruising charge." Regenerative braking switches the electric drive motor to generator mode, slowing the vehicle, recovering kinetic energy to convert it to electric energy, and storing it in the battery bank.

All DC motors can become generators if you turn the motor by force. The faster you turn it, the more electric

power you can generate. In a hybrid, when you press your foot down on the brake pedal, the brakes are applied—but the motor is also used as a generator, which also slows down the vehicle. Some of the braking force is converted to electric energy rather than heating the brake pads and rotors. Besides helping recharge the battery, this also extends the life of the brake pads and rotors. The amount of regenerative brake energy depends on the battery pack's state of charge. If the battery is low, the engine computer will configure regenerative braking to recover as much energy as it can. Many HEVs have two gauges—one that shows energy going into or out of the battery (charging or discharging the battery bank); another shows the state of charge. Along with the real-time mpg gauge, these are the two most important gauges to pay attention to for optimizing performance.

Driving a HEV like a normal car will yield fairly good gas mileage, but mastering regenerative braking means more energy stored in the battery and therefore less gasoline used. Driving more consciously is the key to wresting more mpg performance from regenerative braking. This is not always easy when you have passengers in the vehicle—especially children—but it becomes easier with practice. Most good driving guides stress paying attention to the road and planning as far ahead as possible, while also being aware of the vehicles behind you—and this certainly applies to driving a hybrid effectively.

To optimize the benefits of regenerative braking, plan all of your stops in advance and ride the brake gently for as long as possible until you come to a stop. Braking puts a lot more energy back into the battery than coasting with your foot off the accelerator. This is not always practical in traffic and doing this to extremes will certainly annoy the other drivers on the road. But used appropriately, it is an excellent HEV fuel-saving strategy.

Addressing Your Acceleration

To prevent wasteful idling, HEVs will usually shut down their ICEs at a stop, so plan your acceleration strategy according to how fast you expect to go when you take off. If you accelerate gently, the vehicle will remain in EV mode longer before it switches on the ICE. If you are stopped at the top of a hill, you can use gravity to assist your acceleration, reducing your need to depress the accelerator.

In city driving, accelerating very gently will keep you in EV mode longer if you remain below about 25 mph—any sudden pressure on the accelerator is likely to kick on the ICE. One way of looking at accelerating in a hybrid is to see how lightly you can hold your foot on the accelerator and still maintain the speed that you need. Most drivers tend to press on the accelerator much harder than is actually needed to maintain speed. Watching the real-time mpg display on the dashboard will help you get a feel for this (see "Scan Gauge" sidebar).

Let's say you're planning a round trip from your rural home to do some town shopping and your route in town consists mostly of low-speed driving (below 25 mph). If you can plan your driving so that you enter town with a fully charged battery bank, this will give your car the maximum EV range. For instance, if you have a long downhill run on the way into town, you can either drop the vehicle into low gear on that hill if it is quite steep or feather the brake pedal all the way down, or both. Using low gear turns the engine generator faster, extracting more energy from regenerative braking while also limiting the speed of the vehicle. Riding the brake gently without necessarily slowing the vehicle, especially at speeds above 45 miles an hour, will put a lot more charge in the battery than simply keeping your foot off the accelerator (coasting).

Hypermiling

"Hypermilers" go to considerable extremes to get high gas mileage—many can more than double the rated mpg of their vehicles in ideal conditions. While these strategies are not always considered safe or prudent, they can be used judiciously on open roads with light traffic. One technique that works well with the Prius is known as "pulse and glide." The practice is to accelerate up to 39 mph using the ICE. Then, you remove your foot from the accelerator so the ICE shuts off, and coast down to 33 mph. This repeated process can help increase your mpg on long, straight, fairly level roads. Some hybrids require riding the brake very gently for a few seconds to shut off the ICE. While the car is gliding, be sure you are neither using regenerative braking nor engaging the ICE. Maintaining a coasting glide on level ground takes some accelerator finesse, so don't be discouraged if you don't get results at first. A Web search for "hypermiling" will yield a wealth of information for your specific vehicle.

Stress Sucks Fuel

Responsible, think-ahead driving makes you a better driver—but it also helps to be relaxed. The Discovery Channel's *MythBusters* team tested the hypothesis that a car gets better gas mileage when you are driving relaxed. They had the same drivers drive the same course once when they were very relaxed, and once when they were extremely agitated. They showed that driving while relaxed improved gas mileage significantly. No big surprise, since the relaxed drivers weren't taking out their aggression on the accelerator.

Going the Extra Mile: Tips for Wiser Driving

Lose the Lead Foot

If there is a single rule that says almost everything, it is this: Aggressive, impatient driving (quick starts and stops) produces the worst mileage. At highway speeds, this behavior packs a wallop, shaving off more than one-third from your car's fuel economy.

- In stop-and-go traffic, try to find the speed that you can hold as constant as possible.
- Never tailgate.
- Accelerate moderately, and avoid unnecessary acceleration, such as over a short distance before a turn or stop.
- Keep a steady foot on the gas pedal—accelerating and decelerating can significantly decrease your mileage.
- Delay acceleration for short distances if doing so allows you to use a downward slope to take advantage of gravity.

Cruise & Coast

In all vehicles, it pays to plan ahead for braking.

- Instead of keeping your foot on the throttle up to the instant you switch to the brake, learn to use the third state of driving—coasting. If you see the light turning red ahead of you or traffic bogging down, lift off the throttle and coast.
- When possible, slow down gradually. Try to avoid heavy braking unless it's absolutely necessary.

Don't be a Drag

At higher speeds, wind resistance steals most of a car's power. This varies from car to car, and depends on a lot more than the vehicle's aerodynamics. For pickup trucks, a tonneau cover over the bed can make a real difference.

- At low speeds, use "natural air-conditioning" (open the windows); at high speeds, turn on the mechanical air-conditioning.
- Keep the body in good shape. Dents are not aerodynamic.
- When it rains, slow down for good mileage, regardless of the type of car you have. Pushing air around is one thing—but pushing water around is even more difficult, especially at high speeds.

The Cold, Hard Truth

One of the jobs of a cold engine is to warm up, and it takes fuel to do this. And any car, regardless of type, gets worse mileage when its engine is cold.

- Try to eliminate short trips, especially those followed by long intervals, when the engine can cool.
- Limit or eliminate unnecessary trips in cold weather—or any weather, for that matter. Plan ahead to do multiple errands on a single trip instead of making multiple trips.

Go on a Diet

Not you, but your car. Every extra 100 pounds you carry around cuts 1% to 2% from your fuel economy.

- Clean out all of the extraneous clutter in the car, including in the trunk and under the seats, and only keep the items that you really need.
- Lighten your load. Replace a full-size spare tire with a space- and weight-saving "limited-use" spare. This will also encourage you to fix or replace a flat tire promptly. If you have back seats you rarely use, take them out and store them at home.

Keep it in Shape

Several simple things can make a big difference in fuel economy for any kind of car.

- Get your car serviced promptly when it is due. Tuning up a car can improve mileage an average of 4%.
- Replace the air filter regularly. A clogged, dirty filter can suck up to 10% from your mileage.
- Keeping your tires properly inflated can improve your car's fuel economy up to 3%.
- Stick with the fuel your manufacturer recommends, and change the oil early and often. This can improve your mileage by 1% to 2%.

—Adapted from "Wise Driving: Outsmart the 7 Worst Gas Guzzlers," in *HP111*

Pushing the Boundaries

There are two thresholds to be aware of in most HEVs. One is the speed at which the ICE will always kick in from EV mode, even if you are going downhill or coasting. This usually occurs at about 40 mph. Similarly, you can drop your car into EV-only mode while coasting or slowing to below about 40 mph. The other threshold is the upper limit for acceleration in EV mode, which is about 25 mph. Being conscious of these thresholds will help you to maintain EV mode longer.

Here in rural Maine, most of our driving is on rolling, two-lane blacktop roads where the average speed is about 50 mph. My strategy is to allow the vehicle to slow on the uphill run, using the ICE minimally. At the hill's peak, I feather the brake slightly, which causes the ICE to shut off and allows the vehicle to accelerate downhill using gravity. If the hills are gentle enough, by staying below 40 mph, I can stay in EV mode rather than having the ICE kick in for every uphill run.

Real-Time MPG: Not Just for Hybrids

Getting good gas mileage in any vehicle requires conscious effort and attention to detail, and having a real-time display of fuel economy can provide a clear picture of your driving efficiency. You don't have to buy a hybrid to do this—if you have a vehicle that was made after 1996, you're good to go. Several manufacturers, such as PLX Devices (KIWI) and Linear Logic (Scan Gauge), offer real-time mpg gauges, which will help you achieve your hypermiling goals.

The Scan Gauge II meter displays real-time data on a small screen that you stick to your dashboard. The meter plugs into the on-board diagnostics computer port that's standard on any vehicle made since 1996, the year that OBD-II specification was made mandatory for all cars sold in the United States. You'll recognize this as a rectangular connector found somewhere under the dash. The Scan Gauge can be configured to show four parameters, including real-time mpg that updates every 2 seconds. Other useful features monitor engine temperature, oil pressure, and even the temperature of the air entering the engine. But simply watching the real-time mpg is an education in any vehicle, since you can use this data to immediately adjust your driving strategy to the road conditions.

It is eye-opening to see a vehicle's fuel economy plummet from 30 mpg to 8 mpg on acceleration, and then bump up to more than 100 mpg when you take your foot off the gas going downhill. My Ford Escape hybrid did not come with the fancy computer console, so I installed this gauge to monitor real-time mpg and battery state of charge as a percentage. By pressing a few buttons when I return home, I also can review my mpg per trip, day or tank. The simpler KIWI shows only fuel economy info (see Access).

Courtesy Guy Marsden

With no other vehicles in sight, I can allow the vehicle to slow below 25 mph at the peak of each hill, and then gain speed by the bottom of each hill, usually up to 45 mph. On steeper downslopes, I ride the brakes, staying below 40 mph and charging the battery. My Escape is nominally rated at 30 mpg on the highway and I have achieved up to 40 mpg using this technique. Of course, I pay attention to the road and resume a more normal driving strategy with vehicles behind me, or I pull over to let them pass.

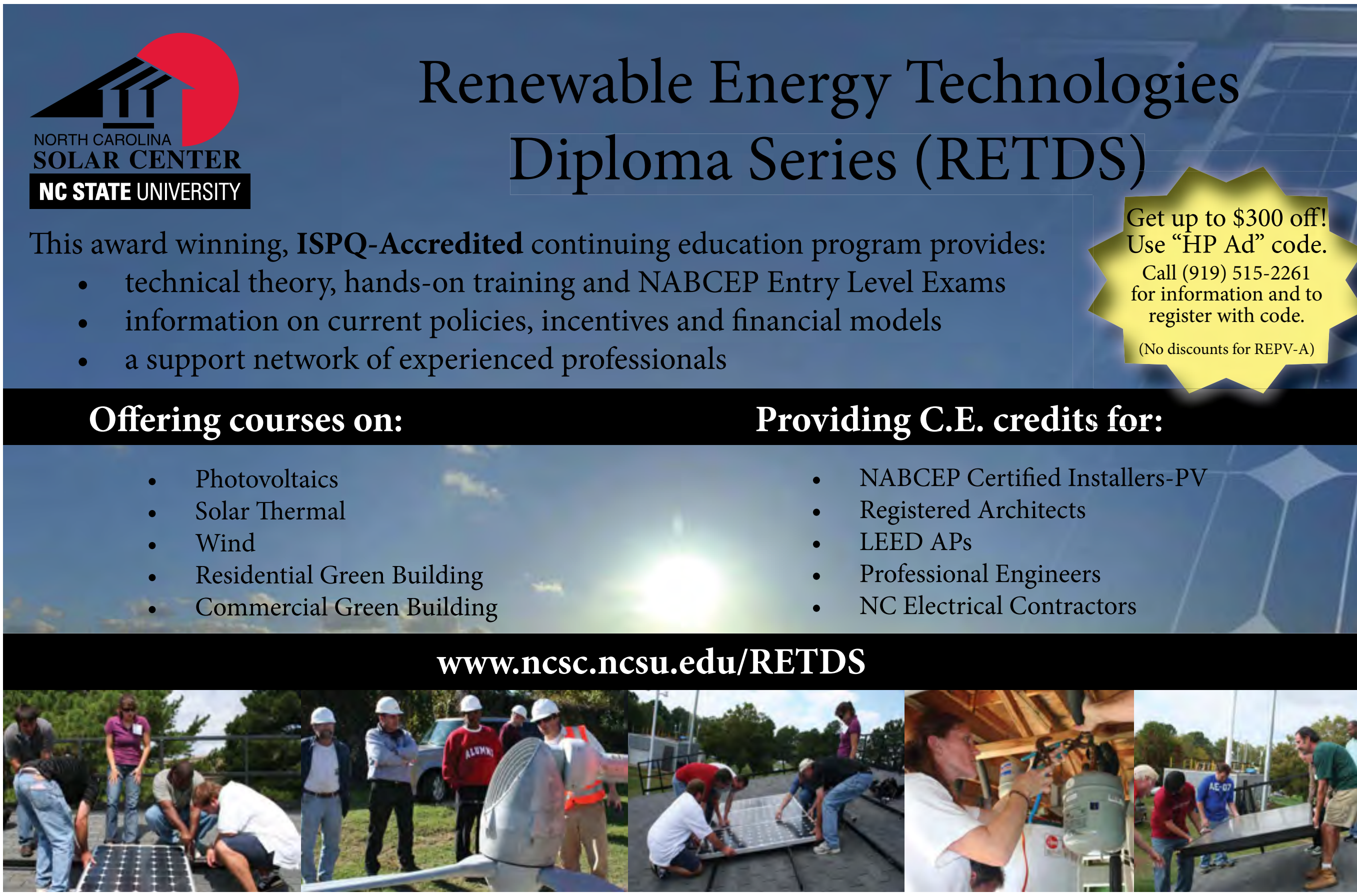
Access

Guy Marsden develops electronic prototypes of electronic products for individual inventors and small companies. He also manufactures differential controllers for PV-powered solar thermal systems. His website (www.arttec.net) showcases his sustainable efforts in considerable detail.

Performance Meters:

KIWI • www.plxkiwi.com

Scan Gauge • www.scangauge.com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GROWING SOLAR

IN YOUR COMMUNITY

by Eugene Buchanan

The community-owned solar garden: a revelation in clean energy adoption.

A solar concept in Carbondale, Colorado, allows those who can't have PV systems—either because of financial hurdles, shady sites, or rental situations—to still reap the benefits of renewable energy. The Clean Energy Collective (CEC) allows people shift to locally produced, renewable energy by buying into a community array and receiving credits on their monthly utility bills.

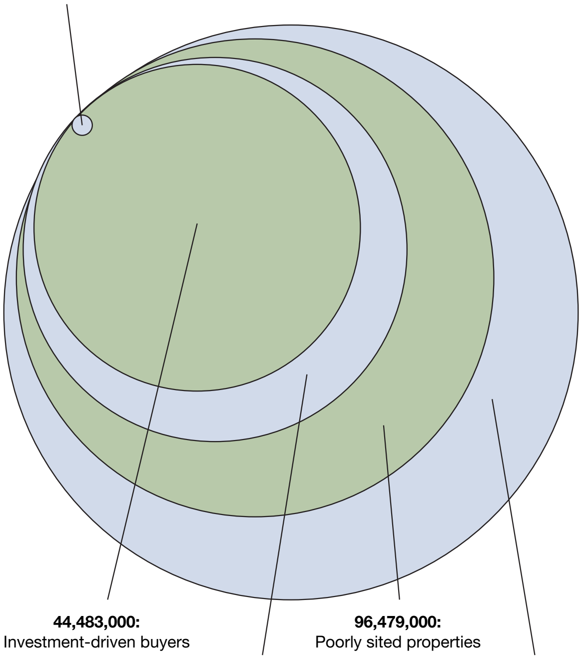
"It opens solar ownership to everyone with a utility bill," says founder Paul Spencer, estimating that it will increase Colorado's solar adoption in megawatts by 67% in the next five years. "It's not supplanting people who can and want to put it on their house, but rather expanding the market to the other 98% of electricity users."

The concept is based on an organization that builds, operates, and maintains community-based clean energy facilities, collectively owned by participating utility customers. And its members reap the benefits of solar energy—including net metering, tax credits, and rebates—without having to install their own systems.

Courtesy Tim Braun

Clean Energy Collective founder Paul Spencer says that the solar garden model can "open solar ownership to everyone with a utility bill."

How the CEC's Model Could Leverage PV Installation Potential



The Key

The idea of collective ownership in a "solar garden"—a centralized, community-shared array—isn't new. Spencer's model takes it a step further than previous efforts in other communities by providing the legal, tax, monitoring, and billing interface to integrate it all with local utilities.

Behind it all is the CEC's RemoteMeter, a custom software package providing remote metering capabilities for CEC customers. The system integrates with utility billing systems to track and apply monthly clean energy production credits directly to the customer's bill. It also lets customers and the utility monitor real-time energy production and account information online or via mobile devices, such as smart phones.

The first hurdle was devising an organizational and legal structure that avoided complex operational and administrative burdens, navigated securities regulations, and let members qualify for tax and rebate incentives. The billing structure also had to account for and automate monthly solar production credits on members' utility bills without burdening the utility. "It had to be simple for everyone involved," says Spencer.

RemoteMeter tracks the energy production of each individual owner/member's portion of a collective energy facility. This data, driven by real-time meter and telemetry readings, is stored for processing and reporting to the utility, enabling customers to realize net-metering benefits directly on their utility bills. Customers are credited directly on their utility bills for the energy their portion of the PV system produces. Depending on the utility, the credit can take the form of a dollar amount reduction—typically through a Power Purchase Agreement (PPA)—or as a kilowatt-hour credit through either a PPA, net-metering agreement or other mechanism in place.

Customers can acquire PV modules—and their resulting power production—in the facility by either direct purchase or a "financing sale" model. Purchases are made on a per-module basis and the customer holds title to the modules purchased. All the customer has to do is contact the CEC, look

at a few utility bills to determine historical energy use, and then decide how many modules to purchase.

Also Beneficial to Utilities

While the CEC's model makes PV energy available to everyone on the grid, it's also appealing for utilities, providing them with reliable, utility-scale clean energy—with the capital provided by utility customers. "It's great to get local renewable energy off the ground, and this is one more arrow in our quiver to meet our renewable energy quota by 2015," says Del Worley, CEO of Holy Cross Energy, which provides electricity to most of Colorado's Roaring Fork Valley consumers.

The utility doesn't have to maintain or monitor the array. "A vital benefit is that it's a utility-scale community system that's fully integrated with the utility and, more importantly, one that's operated and maintained outside the utility," adds Holy Cross Energy's Steve Casey.

CEC facilities are maintained for 50 years through a self-funded operations and maintenance escrow trust, initially capitalized through a portion of PV module sales and then continually fed by a small percentage of earnings for the energy produced, which is designated to the escrow trust. This trust provides funds for cleaning and, if necessary, replacing modules or making needed repairs to or replacement of other components.

The Impetus

Going green is nothing new to Spencer. An electrical engineer, in 2004, he designed and built his own off-grid home, heated by the sun, and powered by PV and wind-electric systems. Later, he spearheaded the development of sustainably developed neighborhoods and homes, including a pending 89-home development to be powered by a 300 kW central PV array.

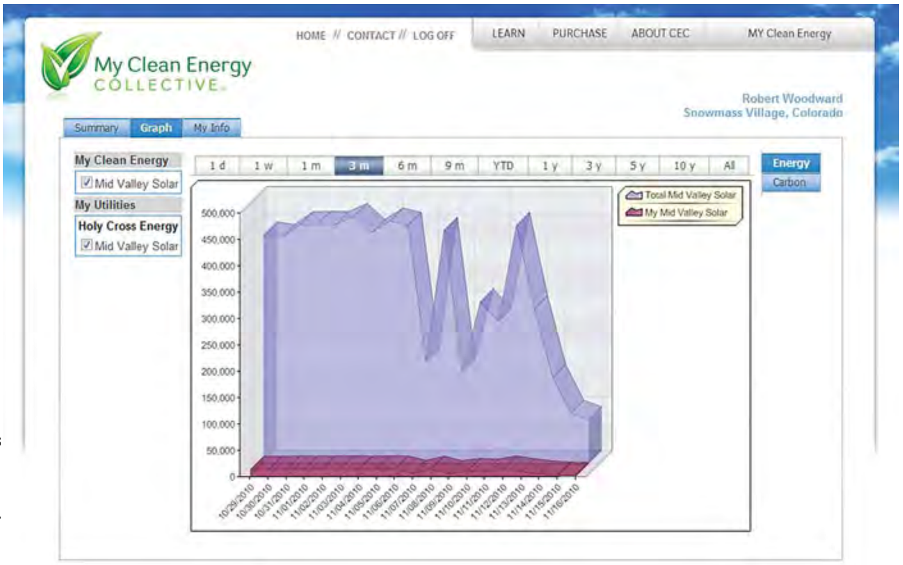
Supported by Holy Cross Energy, that project set the stage for the community energy concept. Spencer realized that the most efficient way to incorporate clean energy into the project wasn't to put a system on each home, but to aggregate the production into a single site. After vetting this idea with the local utility, his vision grew and the CEC was born.

Getting Off the Ground

In the spring of 2010, the CEC closed on a long-term lease to build its first member-owned array on land owned by the Mid Valley Metropolitan District (MVMD) in El Jebel. Housed on a 1/3-acre parcel of land unsuitable for development, the facility now hosts a 338-module array (77.7 kW) serving 19 CEC members. The $500,000 investment—including the land lease and cost of the PV array—was funded in a few weeks with 83 customers paying $6 per watt for ownership (the actual price was as low as $2.45 per watt after rebates, discounts and credits).

The CEC's first member-owned PV array in El Jebel, Colorado.

PV system output data can be accessed via any web-enabled computer or smart phone.



Courtesy Clean Energy Collective

The system began producing energy in August, with members receiving their first credits in October, the lag due to the CEC ensuring that the array was performing up to standards prior to transferring ownership to its 19 homeowners. Spencer says the wait period will not occur in the future.

"It's a great use of the land," says MVMD executive director Bill Reynolds, who explains that the power generated by the array goes directly onto the Holy Cross Energy grid. "And CEC members actually own the system."

While the pilot facility is the second-largest PV array in the Roaring Fork Valley, it's a drop in the bucket compared to the CEC's other plans. In July, the CEC closed on its second lease for an array that will also send energy to Holy Cross Energy. Located at the Garfield County Airport near Rifle, the 5-acre site will produce 15 times the electricity as the El Jebel site. With 5,200 modules, the 1.2 MW facility will be the largest privately owned PV array in the state, serving as many as 500 CEC members. It is scheduled to go online by this summer.

The CEC is far from done. It's currently in negotiations to build several more systems, including a 2 MW facility in Eagle County on 8 acres of capped landfill near Wolcott; a 400 kW site on 1.5 acres in Snowmass Village; and a second site in El Jebel—1.2 MW on 5 acres. "We're rolling," says Spencer. "We want to start making clean energy available to absolutely everyone in the Valley and beyond."

Politicians Seeing the Light

Like any good idea, timing is everything—and Spencer's couldn't have been better. While he was launching his first project, local politicians were also championing the solar cause. U.S. Senator Mark Udall (D-CO) announced a new bill to create jobs, strengthen the clean energy industry, reduce taxes and increase the nation's use of solar energy. His Solar Uniting Neighborhoods (SUN) Act of 2010 modernizes the federal tax code regarding solar energy. If it passes, homeowners who invest in community solar projects would be able to take a 30% tax credit—just like those who install PV systems at their houses.

This push for clean energy use shows: Colorado currently ranks fourth in the nation in clean-energy employment and has the second-highest renewable energy standard for utilities.

The Economics

Aside from environmental and social benefits, consumers want affordability. And that's where the CEC model shines. The solar garden "has a very low entry cost for ownership," says Spencer. "Our members leverage their collective purchasing power and buy as little or as much energy equipment as they choose at reduced prices." Economies of scale give the CEC excellent cost per watt.

At the El Jebel site, the gross consumer cost, including installation, was about $466,000 ($6 per W). After rebates and incentives, the 19 members paid an average of $3.15 per W. Some members bought only one module, while others purchased up to 87, with the restriction that an individual's modules could not produce more than 120% of their household electricity consumption. The buy-in was a 30% refundable deposit. The remaining 70% of the net cost was paid after the facility was completed. The CEC is working on consumer financing solutions for future projects.

Each month, Holy Cross Energy credits the members' utility bills at $0.11 per kWh (a premium over HCE's conventional $0.08 retail rate). Credits are calculated based on the number of modules owned and the amount of energy produced by the facility each month. If utility rates increase, the credit for the CEC-generated kWh will continue to be 37% above those future rates.

Catching on with Consumers

So far, it's been a relatively easy sell. With the CEC model, customers reap the same federal tax benefits of PV ownership at home (currently a 30% credit), without having systems installed at their residences. Because it's a managed, reliable system with power coming from one source, customers also get better electricity rates. Through the Power Purchase

Courtesy Mark Boyer

Courtesy Mark Boyer

Through the "solar garden" concept, homeowners in Colorado can reap the clean energy benefits of this PV system, even though it is not installed at their homes.

Agreement (PPA), the utility pays a higher rate to community solar members than it does to home-sited PV customers ($0.11 per watt versus $0.08 per watt).

"I love the fact that we can own a solar power [system] that will be maintained, up-to-date and hassle-free," says Katie Ertl, one of the first members of the Mid Valley array. "It lets us pay attention to the environment and use green energy, with the experts supporting us along the way."

Plus, there's another attribute: "Many people can buy renewable energy [through utility companies' green energy programs], but that energy is usually sourced from far away or traded, and the customer doesn't own the energy source. This is like buying the cow, not the milk," says Spencer. "This is based where you live, improving the air quality and economy locally. And when milk goes to $5 a gallon, you'll be glad you own a cow that produces your milk for free."

And that resonates well with locals around the outdoor meccas of Aspen and Vail. "We've been trying to reduce our fossil-fuel consumption for years, but when it came to making the switch to solar, there were some issues we couldn't overcome," adds Aspen resident Chris Davenport. "The first was price; the second was our roofline. Now, we can own the renewable energy we want and at a fraction of the cost. And the energy is generated in our own valley."

Support from the local governments is vital. In November, Eagle County commissioners modified its ECO-Build Rebate program to allow "off-site" PV customers to apply for the same incentives as individual customers. The decision lets residents who invest in community arrays enjoy the same rebates as homeowners—reflecting the county's commitment to encourage all residents to invest in solar electricity. "The Eagle County decision is a big step forward for community-owned PV owners being treated the same as homeowners with individual rooftop systems," says Spencer. "Many counties and states are following suit."

The Sky's the Limit

The CEC's program is good news for RE in Colorado, and the company hopes to expand even further. From the onset, it focused on ensuring the model could be replicated and exported, and those efforts are paying off.

The CEC is currently in conversations with more than three dozen potential licensees interested in exporting the model across the country. The company is working on a joint venture with two other partners—a finance company and a multi-billion-dollar solar integrator—to deploy the model in 10 key solar states, including Florida, Texas, and California.

"We're even getting inquiries from businesses in other countries that want to franchise what we're doing," says Spencer, adding that he's also in discussions with other Colorado utilities that are assessing how the model fits into their clean energy strategies. "We've proved the concept locally and now want to take that blueprint to branch out elsewhere."

By the end of 2011, Spencer estimates the CEC's community-owned arrays will provide 5 to 10 MW of capacity in and outside their local area, with that number eclipsing 100 MW nationally by 2015. "It could go from there to gigawatts very quickly. In my dream world, [the program] is a catalyst that creates a quantum leap in the adoption of clean energy."

Access

A former reporter for the *Denver Business Journal*, Eugene Buchanan (ebuchanan@steamboatpilot.com) has written about the environment and outdoors for more than 25 years, with his works appearing in *Outside*, *Men's Journal*, *National Geographic Adventure*, and *Sierra* magazines, and ESPN. While community PV options don't exist yet in his home in Steamboat Springs, Colorado, he's looking forward to their arrival.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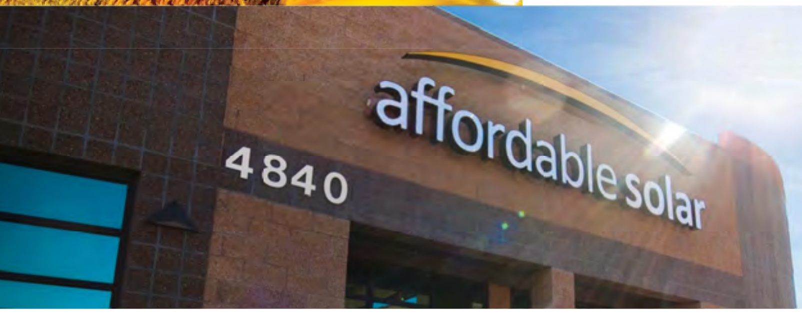

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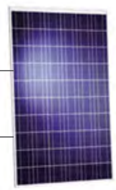

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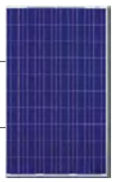

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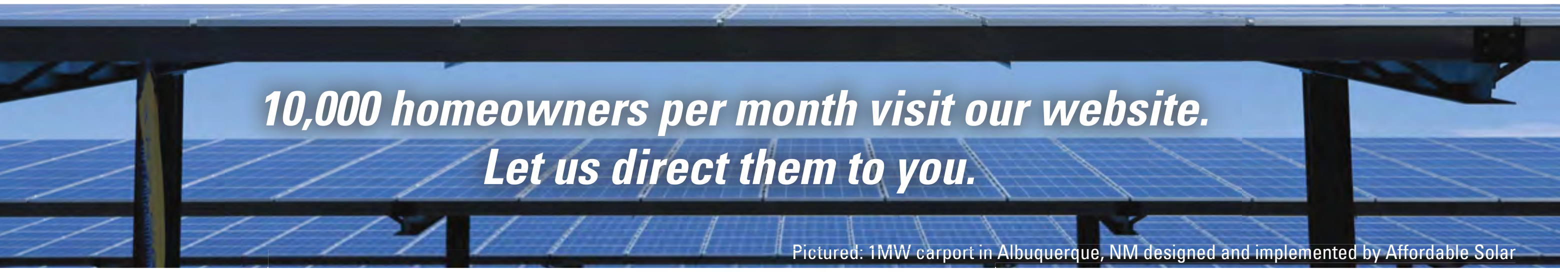

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Potential PV Problems

& New Tools for Troubleshooting

by Justine Sanchez

Shawn Schreiner

Courtesy dissigno

Soiling is not always obvious until you start cleaning, but it can reduce PV module output significantly.

Several situations can affect a PV system's output, and new troubleshooting tools are available to help identify system losses and take some of the guesswork out of pinpointing the problems.

Production-based incentives, which pay system owners based on the amount of energy (kWh) their systems generate, make keeping an eye on system performance even more important than for other incentive programs. Being aware of common array problems, knowing how to maintain the system, and understanding how to evaluate performance (and how to troubleshoot) are vital to keeping performance and incentive payouts at their peak.

Potential Array Problems

While PV systems have no moving parts (compared to wind and microhydro systems) and can be extremely reliable, it does not mean they do not have potential performance problems, which can stem from external and internal issues.

External issues, such as shade from growing trees and module soiling (dust or soot from local air pollution), are common problems that can reduce energy output significantly. Studies on module soiling show an average annual energy loss of 5% for arrays that are not periodically cleaned. These types of problems are usually easily solved by intermittently trimming vegetation and cleaning arrays.

Impact to PV systems from critters is another external issue, but one that takes a little more consideration to fix. Wires might be damaged by rodents chewing on them; modules soiled by birds pooping on them; or cells shaded by weeds sprouting between the module frames from dirt and/or bird "fertilizer" beneath the array.

Courtesy Tony Diaz

A failed attempt at keeping pigeons from nesting under a PV array: Not only did weeds grow from the droppings, shading the array, but some of the screen has come loose and contributes to shading, too.

Courtesy Alteris Renewables

Bird spikes, placed on the rack before the modules are mounted, effectively keep birds from roosting on and soiling modules.

The fix-it for stopping critters in their tracks is to install rodent barriers and/or bird spikes. Many installers are tackling this problem preemptively, including some kind of screen or wire that keeps critters out but allows air to flow beneath the array.

Internal problems, such as module/cell damage, can also reduce system output. Sometimes these problems are easy to spot, but often they are not.

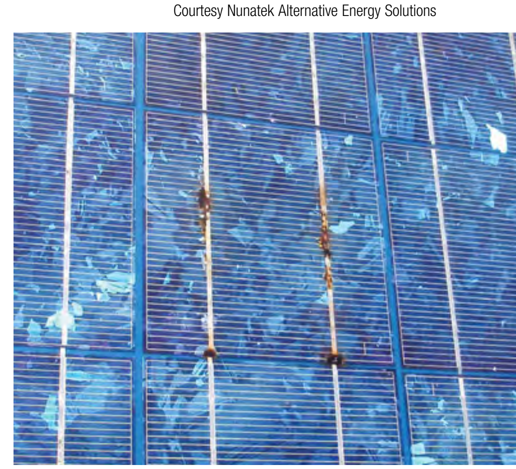
Visually inspecting the PV array once a year is a good idea. Look for cracks in the glass, brown/burn spots on both the front and the back of the modules, burnt solder joints on the cell "grid," and signs of delamination and cell damage.

This module suffers from delamination between the glass encapsulant and several PV cells. The cell to the upper left also appears to have moisture-induced corrosion.

Courtesy Southwest Technology Development Institute

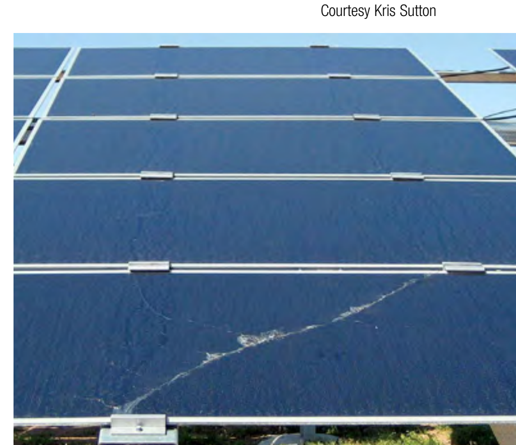
Sometimes, module defects, such as this broken cell, can be spotted before the module is installed.

Courtesy Nunatek Alternative Energy Solutions



The bus bars and cell interconnects on this module have high electrical resistance, leading to extreme hot spots and actual burns on the bus bars, interconnects, and even on the polymer backsheet (not shown).

Courtesy Kris Sutton



Cracked glass encapsulant allows water intrusion, which can cause corrosion and even a shock hazard.

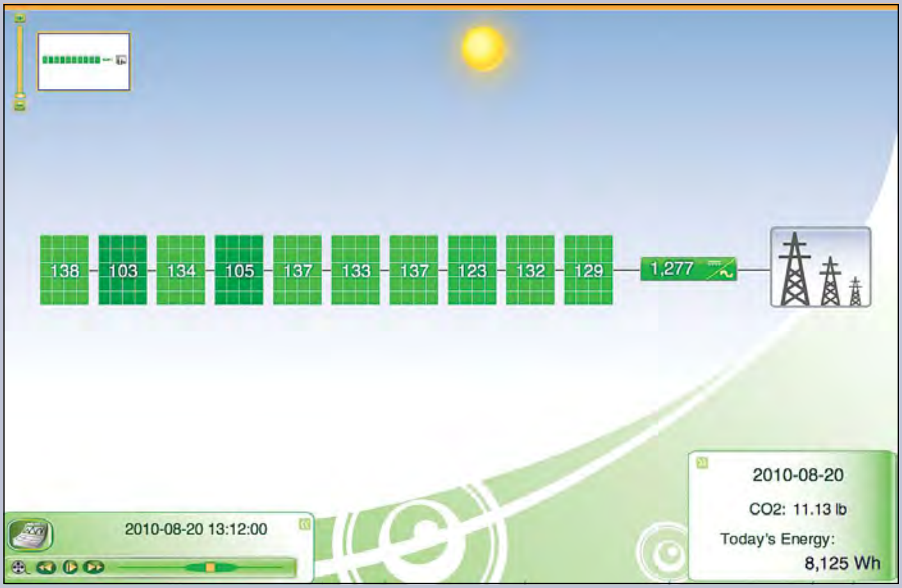
Shawn Schreiner

Tools: Module-Level Monitoring & IR Cameras

My family installed our 1,700-watt PV system late in the summer of 2006 (see "Creating a Brighter Future" in *HP118*). We were immediately impressed with our system's performance and continued to check actual output versus our projected production each season.

The result of our data-gathering revealed that our annual kWh production was about 10% less than projected. We attributed the energy loss to array shading. In the summer, an overhang partially shades the eastern-most modules until 10 a.m., and a willow tree on the west starts to shade the western-most modules as early as 3 p.m.

In May 2010, in an attempt to reduce the effects of our partial array shading, we installed Tigo Energy Module Maximizers, which have individual module monitoring. And while we are still unsure whether or not the shading problem has been reduced, the value of the module-level monitoring was immediately apparent. Within minutes of adding the units, problems with our Mitsubishi modules No. 2 and No. 4 were identified. Under sunny conditions, the power output from these two was about 22% less than the other modules. Additionally, module No. 8, while not as low as No. 2 and No. 4, seemed to be underperforming as well (about 8% lower). We suspected faulty bypass diodes, but the junction boxes are potted and there was no easy way to test the them.

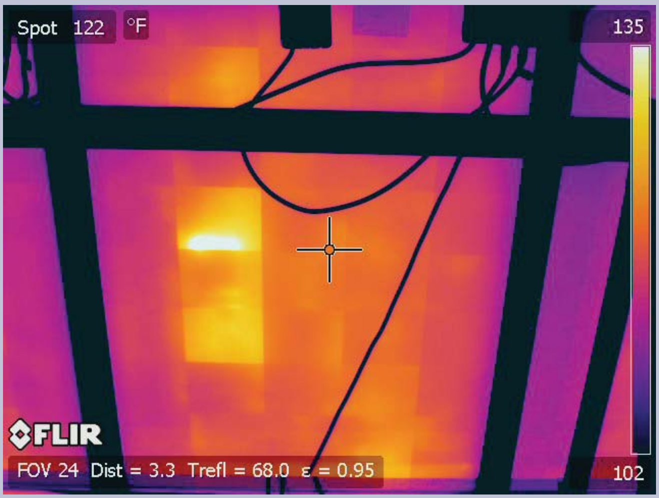


This screen shot shows lower wattages for modules No. 2 and No. 4. Module No. 8 is also slightly lower.

Because I was having difficulty getting a response from the module manufacturer, I contacted a friend who works in PV manufacturing for advice on troubleshooting the modules. She suggested using an infrared (IR) camera to identify either hot cells or solder bonds or even warm (active) bypass diodes. I located an older, black-and-white IR camera through our local utility. They sent their renewable energy engineer, Jim Heneghan, over one sunny afternoon. Using the camera, he quickly found glowing white spots on all three modules.

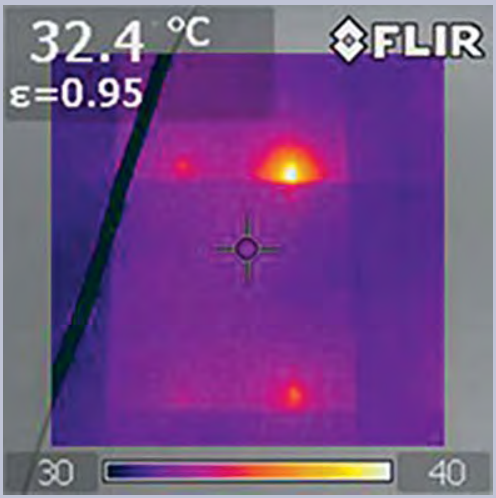
In researching common internal module problems and showing the photos to friend and colleague Bill Brooks, I believe that my modules were suffering from poor solder bonds and perhaps shunted cells. I filed the warranty claim, including the IR images and Tigo screen shots as further evidence for the modules' malfunctions. (Note: In preparation for writing this article, I got color IR shots thanks to a loaner camera from FLIR and HERS rater Gary Handelin.)

These hot spots register about 15°F to 20°F warmer than the other module areas.



Courtesy Justine Sanchez (2)

When you zoom in on this module's hot spots, it is easy to see that they match up with the location on both bus bar interconnects between cells.



Courtesy Gary Handelin

The modules have now been replaced under warranty, and are installed in my system. To be safe, I took IR images of the newly installed modules in the array to spot any problems. So far, the replacement modules seem to be working just fine, and no hot spots were detected on the new modules in the array.

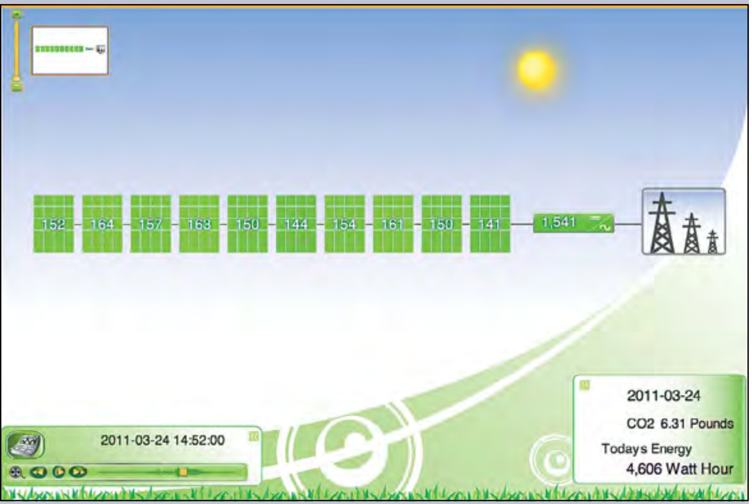
It took me awhile to receive a response from the module manufacturer, possibly because, like many manufacturers, they have not had to handle many warranty claims. However, in a few years, the rise of module-level monitoring may change this. While the number of installations with module-level monitoring is rapidly growing, these are primarily with new systems and new modules, and module issues may not arise until after several years of sunlight exposure. At this point, the number of systems with older modules (ours are four years old) and module-level monitoring are very few.

Over the system's projected 25-year life, the energy loss due to the malfunctioning modules would have equalled about 3,400 kWh—what our entire system typically produces in a year and a half. But I also think about the energy it took for me to chase down the source of the problem, as well as the carbon footprint for returning the old modules and shipping the replacement modules. Considering those factors, I'm not sure if the net energy result is one in our favor or not. But I am pleased with what IR cameras and module-level monitoring have to offer to PV system troubleshooting, and I am much better prepared should we experience future array problems.

Note: In a search for affordable troubleshooting tools, I also used a Black & Decker Heat Detector (about $50) to see if it could identify module "hot spots." A reference temperature can be set, and if the temperature goes 5.5°C above the reference temperature, the Detector projects a red light. While the Detector does help with troubleshooting, it cannot generate images for use in a warranty claim.

—Justine Sanchez

The Tigo monitoring screen shot shows the results of the module replacements.



System Evaluation & Troubleshooting Tools

If the modules pass a visual inspection, that's a good first step. In many cases, though, module/cell damage is invisible, so it is important to know how to evaluate your system's performance, which can alert you to problems that may be brewing.

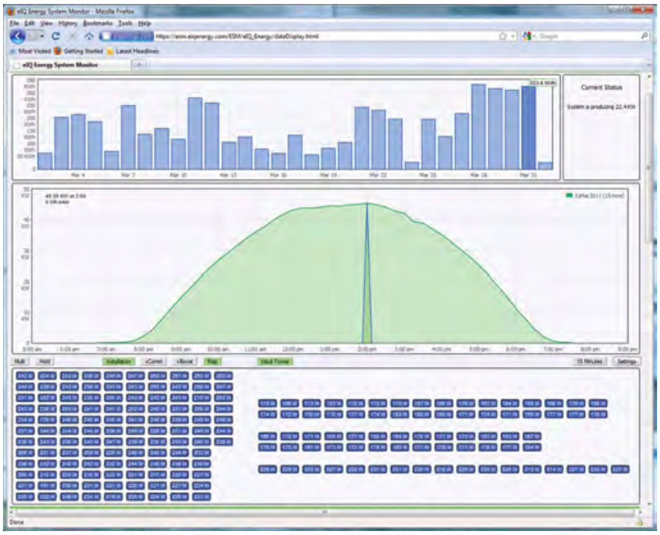
System owners often use the inverter's built-in meter as the primary indicator of system performance. During a clear, sunny day around noon, you can check the system's output (in watts) and compare it to the array size, derated to account for system inefficiencies. System efficiency typically ranges from 70% to 80%. This derate accounts for power losses due to module heating, dust, inverter efficiency, wiring voltage drop, module production tolerance, and module mismatch. For example, a 4,000-watt PV array would be expected to generate 70% to 80% of that value, or 2,800 to 3,200 watts. What action do you need to take if the meter reading is significantly lower than expected?

Inverter built-in meter readings can help users discover bigger issues, such as an entire module string being offline or an extremely dirty array, but they aren't accurate enough to uncover less-obvious problems.

Module-Level Monitoring. Until recently, PV system checking has been limited to evaluating the performance of the entire system. However, products that offer individual-module-level monitoring are now available and gaining popularity. Examples include microinverters and several DC-to-DC converter units, which allow users to view over a computer network each module's output.

For example, if a module is shaded during part of the day, the report or visual display will reflect a much lower power output (or lifetime energy output) for that particular module. And on a sunny day, with a completely unshaded array, problem modules—such as those with damaged cells, solder bonds, or diodes—are easy to spot.

eIQ offers its VBoost DC-to-DC converters, which include module-level monitoring.



Courtesy eIQ Energy

Courtesy Enphase Energy

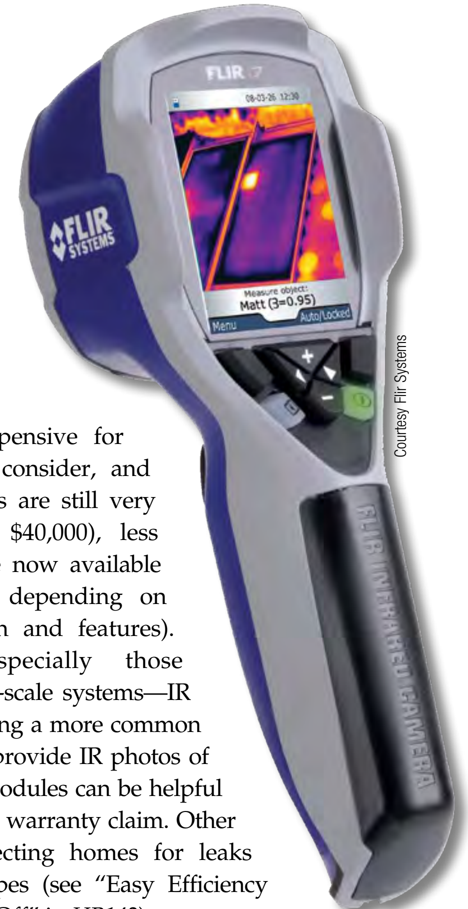
Enphase Energy microinverters interface with the Enlighten website, monitoring each module's lifetime energy performance. In this screen shot, notice that the darker blue modules report lower values, illustrating the impact of shading from a chimney.

Before module-level monitoring, identifying a 33% reduction in output from one module (from one bad diode, when a module has three) would typically go undetected for the lifetime of the system. This is because the partial energy loss from an individual module only represents a small loss to the system. For example, in an array with twelve 250-watt modules, the loss of one diode in one module would cause less than a 3% loss to the system. Compared to a general derate of 20% to 30%, the loss due to the bad diode would be undetectable. While this loss may seem small, the lost energy production over the system's lifetime adds up (see "Tools: Module-Level Monitoring & IR Cameras" sidebar).

PV Analyzer. For arrays without module-level monitoring, installers can check up on PV system health by using Solmetric's PV Analyzer, which graphs a module or string's current-voltage (I-V) and power-voltage (P-V) curves. Because the measurements are very sensitive, they reveal the effects of many types of array damage and degradation, which have "signature curves" that installers can look for. If a problem is detected, the Analyzer can be used on individual modules to pinpoint the culprit. (see "Gear" in this issue). While neither module-level monitoring or the PV Analyzer will tell you exactly what the problem is, they can prompt a closer look at individual modules in the array.

Infrared Cameras. Should a module issue be detected, finding the root of the problem can be tricky. Module bypass diodes are often not accessible for testing or servicing, and PV cell damage is often not visible. Because of these limitations, infrared (IR) cameras can be handy in module evaluation.

The heat generated by a damaged PV cell or solder bond (even an active diode) will show up as bright spots on the photos, pinpointing the source of power loss. Historically, these cameras have been too expensive for most installers to consider, and while many models are still very expensive (up to $40,000), less expensive units are now available ($1,200 to $8,000, depending on detection resolution and features). For installers—especially those working with large-scale systems—IR cameras are becoming a more common tool. Being able to provide IR photos of underperforming modules can be helpful in establishing a PV warranty claim. Other uses include inspecting homes for leaks in building envelopes (see "Easy Efficiency Improvements Pay Off" in *HP142*).



An infrared camera can be a handy tool in troubleshooting PV module problems.

Courtesy Flir Systems

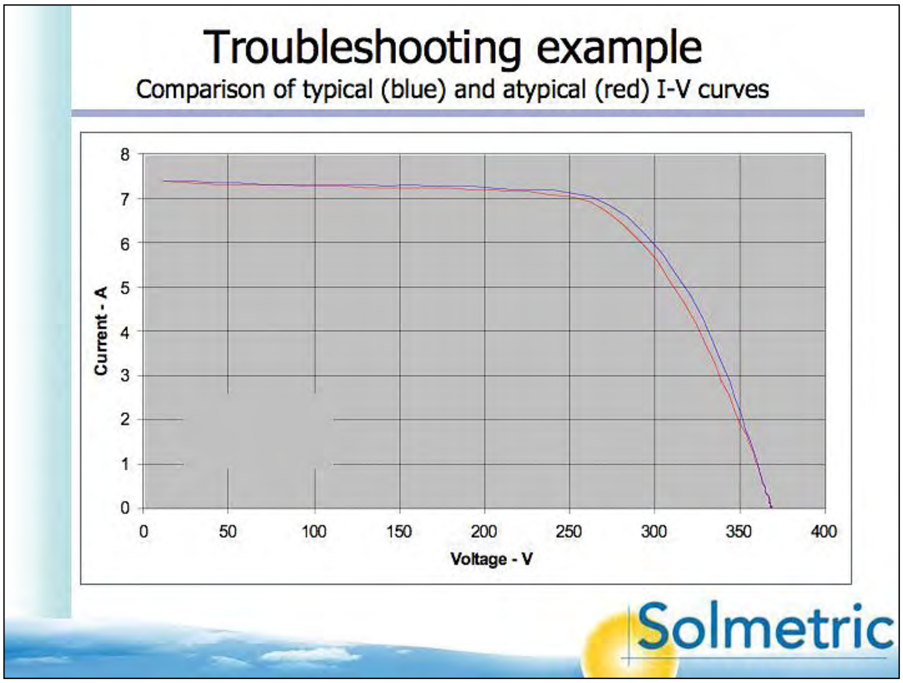
Reality Check:

The Costs of Monitoring & Diagnostic Tools

While high-tech tools are cool, they do come at a cost. Retrofitting an existing system with module-level monitoring requires purchasing the DC-to-DC converters (one for each module), which range from $50 to $140 per unit; and, sometimes, communications hardware (about $600). You may also have to pay annual fees for accessing the data online. On new systems, microinverters or DC-to-DC converters can be installed from the get-go, which may or may not increase system cost. (But be sure to factor in online data access fees.)

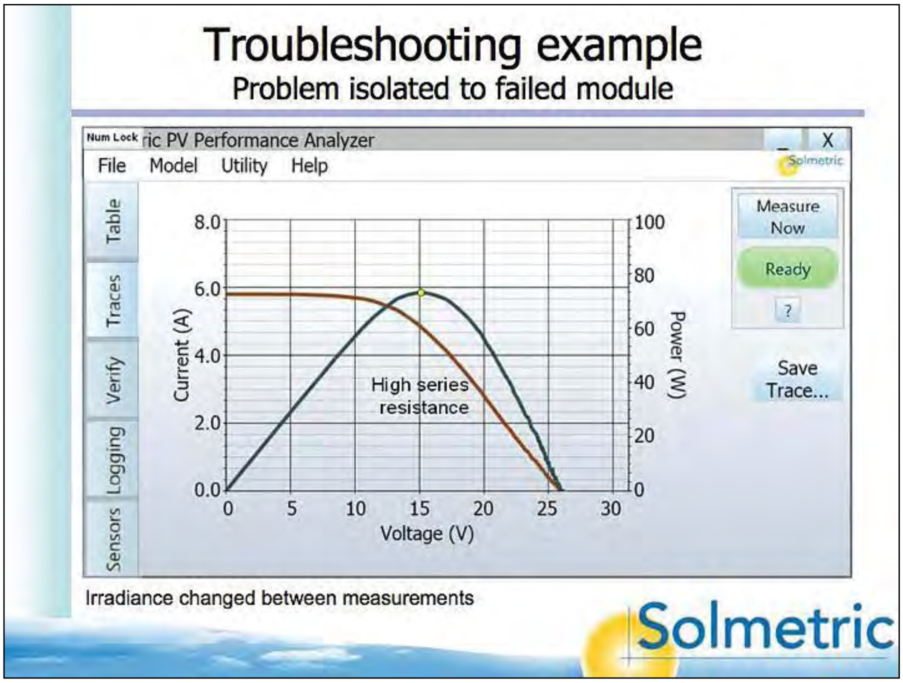
On the flip side, there is much movement between these companies and PV module manufacturers to offer "smart modules," which provide an integrated solution at a projected lower cost.

Diagnostic tools such as the PV Analyzer and infrared cameras are used by professional installers for troubleshooting installations and providing evidence for warranty claims. Even then, it's typically only those installers who deal with large arrays on a regular basis who will be willing—or able—to shell out the bucks for these top-notch diagnostic tools.



Courtesy Solmetric (2)

This pair of curves is from two adjacent strings of polycrystalline modules. Notice that the slopes are different on the right-hand side, indicating that one string (represented by the red curve) could be suffering resistance losses.



One module is the source of the resistance losses in the "red" string (at left). The module's I-V curve is red and its power curve is green. Near Voc, the red curve has a very shallow slope. The maximum power point is always at the knee of the curve, and this shallower slope means that the MPP is at a lower voltage, and therefore a lower power (about 30% less than the other modules). Upon checking, this module showed burn marks along several cells.

Growing Pains & Array Performance

Much of the current photovoltaic industry has focused on reducing the cost per installed watt, which, over the last five years, has dropped—from $10 per watt to between $5 and $6 per watt. This, coupled with incentive programs at the federal, state, and local levels, has resulted in the rapid deployment of grid-tied PV systems on homes and businesses across the country. However, it is possible that the swift ramping up in PV module production to meet this demand may be the source of some of the internal module problems discussed here. The good news is that monitoring options can alert us to problems as they arise, helping system owners maintain their systems and allowing module manufacturers to see their products' performance over a wide range of installations.

Whether you are interested in maximizing your economic return or you simply want to generate as much renewable energy as possible, plan to periodically check your system's output and watch for potential problems. Catching these issues early can keep you from losing precious sun-generated kWh for years to come.

Access

Justine Sanchez (justine.sanchez@homepower.com) is a NABCEP-certified PV installer, *Home Power* technical editor, and Solar Energy International instructor who is now happily watching her new PV modules kicking out the expected watts.

Special thanks to Jeff Krisa and Stuart Davis of Tigo Energy; Jim Heneghan at DMEA; Colin Mitchell and Monali Joshi at Suntech; Gary Handelin of Solar Independence; Bill Brooks of Brooks Engineering; and Jeff Tobe and Kris Sutton of SEI.

Troubleshooting Tools:

FLIR • www.flir.com • Infrared cameras
Fluke • www.fluke.com • Infrared cameras
Solmetric • www.solmetric.com • PV Analyzer

Module-Level Monitoring:

eIQ Energy • www.eiqenergy.com
Enphase Energy • www.enphaseenergy.com
Exceltech • www.exeltech.com
SolarEdge • www.solaredge.com
Tigo Energy • www.tigoenergy.com

The Big Picture for Biofuels

Once hailed as revolutionary fuels, are ethanol & biodiesel delivering on their proponents' promises?

by Brad Berman

It's been more than four years since George W. Bush told the country that we would soon be using wood chips and switchgrass to fuel our automobiles. Unlike corn-based ethanol—widely considered a disaster for its negative net energy and its effect on global food prices—fuels grown from grass and weeds are more promising. Feedstocks for these newfangled fuels can be grown anywhere—like on highway roadsides instead of precious farmland. According to Bush, 75% of foreign oil imports could be replaced with renewable fuels by 2025.

South Dakota-based POET, the world's largest ethanol producer, makes even bigger claims—that fuel from biomass can entirely replace all gasoline from imported oil. Yet, POET's commercial-scale cellulosic ethanol plant—which aims to produce a relatively modest 25 million gallons of ethanol per year from corn cobs, leaves and husks—has faced delays. (Compare this to the 140 *billion* gallons of gasoline consumed each year in the United States, and you can understand that's it's just a drop in the bucket.) Opening of the plant, dubbed "Project Liberty," has been delayed, rescheduled for 2012 at the earliest. A half-dozen other high-profile cellulosic ethanol projects, once thought to be imminent, are similarly stalled due to technology challenges or lack of financing.

Ethanol can be made from high-cellulose plants like switchgrass. But will it be financially or environmentally viable?

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Huge industrial ethanol plants transform corn and other feedstocks into biofuel.

"This is a hard problem, but that doesn't often get communicated," says Jamie Cate, associate professor of chemistry and molecular cell biology at the University of California at Berkeley. Cate's research is affiliated with the BP-sponsored Energy Biosciences Institute, which brings together economists, climate scientists, plant biologists, and biochemists to explore the future of sustainable biofuels. Cate's background is in biomedicine, but after becoming concerned about climate change, he shifted his scientific research to unraveling the mysteries of biofuels.

Biding Time

"We're doing fundamental science research," Cate says. "Discoveries that we're making in the lab now, if they're useful, are going to take several years to scale." Cate believes that cellulosic ethanol will just begin to reach commercial scale in five to 10 years. "It could be faster, but I'm not going to bet on it," Cate says.

The federal government's timetable for next-generation ethanol is starting to reflect the same sober reality. The Renewable Fuel Standard—created under the Energy Policy Act of 2005 as the first renewable fuel volume mandate in the United States—called for 100 million gallons of cellulosic ethanol production for 2010. But when push came to shove, the EPA changed the requirement to 6.6 million gallons per year beginning in 2011. Now, even that goal seems beyond reach.

Ethanol (and biodiesel) pumps are few and far between.

Courtesy SeQuential Biofuels

Not Even Green, As Far As We Know

While we're waiting for cellulosic ethanol to materialize, the U.S. government continues its support of corn-based ethanol. Between 2005 and 2010, the United States provided more than $22 billion in tax credits for blending ethanol with gasoline, according to *The Economist* magazine. Trying to figure out what we got for that expense is no easy task.

"Are biofuels green or clean or low-carbon or sustainable or whatever other slogan is popular to attach to them?" asks John DeCicco, senior lecturer at the University of Michigan School of Natural Resources and Environment, where he teaches and leads research on sustainable transportation energy and climate issues. "No. The vast majority of biofuel now produced is no greener than the vast majority of current resource-intensive production of any other fuel."

DeCicco says the big problem is that there's no systematic tracking of the pollution from either growing corn and soybeans, or from refining those crops into ethanol and biodiesel. DeCicco believes that renewable fuel standards at the federal and state levels are "delusional policy."

Corny Ethanol

Speaking at a November 2010 green energy conference in Greece, former vice president Al Gore says his past support for corn-based ethanol had been just plain wrong. "One of the reasons I made that mistake is that I paid particular attention to the farmers in my home state of Tennessee," Gore says, "and I had a certain fondness for the farmers in the state of Iowa because I was about to run for president." Gore

Global Biodiesel Issues

According to the Union of Concerned Scientists, biodiesel constitutes only a fraction—less than 1%—of diesel fuel use, although that percentage is growing. In 2006, about 250 million gallons were used. In 2009, that number had more than doubled, to 545 million gallons. The irony is that the more this eco-friendly option is used—requiring large-scale production—the less eco-friendly it will likely be. Scaling up production means tapping into either virgin plant oils, like soy or palm, or tapping other waste streams.

The environmental benefits can start to slide when virgin sources are used. For instance, although a study by Argonne National Laboratory showed that "100% biodiesel from soybeans can cut global warming pollution by more than half relative to conventional petroleum-based diesel," their model, says the Union for Concerned Scientists (UCS), didn't account for land-use impacts. The UCS explains: "When soybeans are used for fuel, they are taken out of the market for food. This increases prices and stimulates demand that farmers around the world respond to by bringing more land into cultivation. With soybean production increasing in the Amazon, it is possible that the life cycle global warming pollution of soybean biodiesel is even higher than petroleum diesel, once indirect land use changes are considered."

Beyond land-use issues, says the UCS, "such large-volume biodiesel use could raise concerns about genetically modified crops, pesticide use and land-use impacts common to ethanol and all other plant-based fuels."

Kumar Plocher, president of Yokayo Biofuels in Ukiah, California, agrees: "The depth of ecological devastation from palm and soy oil plantations can be huge. It's unsustainable when diverse habitat or native homelands are destroyed for a monocrop that is then turned into oil and sent halfway across the planet. Still, there might be local soy or palm biodiesel producers in Central America who didn't clear jungle and who deliver the fuel locally—and that's not necessarily unsustainable."

admitted that once subsidies are in place, it's difficult to stand up to "the lobbies that keep it going."

Gore is not alone in finally abandoning the cause of corn ethanol. In 2006, General Motors launched its "Live Green, Go Yellow" campaign, which pushed flex-fuel vehicles that can run on E85, a liquid blend made up of 85% ethanol and 15% gasoline. They've since focused on their new "green" vehicle—the Chevy Volt, a plug-in hybrid car that works mostly like an electric vehicle. Why the shift? Besides the questionable energy benefits of corn ethanol production, drivers pumping E85 personally pay an economic penalty at the pumps: Ethanol has two-thirds of the potential energy of gasoline—meaning a reduction in mpg. Even if the price of E85 at the pump is cheaper than gasoline, using ethanol may not be less expensive in the end.

Moreover, gas stations offering E85 are few and far between. The Department of Energy lists more than 2,000 E85 stations in the United States, but most of those are in five states: Minnesota, Indiana, Iowa, Illinois and Wisconsin. The number of states offering E85 pumps is steadily growing, but to put things in perspective, there are more than 150,000 stations nationwide selling gasoline.

To make matters worse, since 1985, automakers have been allowed to assign flexible-fuel vehicles higher fuel economy ratings under the government's CAFE fuel economy regulations. That's regardless of whether or not the vehicles are ever filled with E85. The flex-fuel credit means the CAFE fuel economy number for a large SUV might get inflated. Ultimately, the E85 CAFE loophole puts more gas-guzzlers on the road, consuming extra gallons of gasoline than the use of E85 was intended to reduce.

Think Small & Local

Images of an oversized SUV with a corncob stuffed into its gas tank have been replaced with sleek photos of the Chevy Volt. In fact, the entire auto industry has shifted its green efforts to vehicle electrification, and has mostly resisted efforts to increase the percentage of ethanol in gasoline blends. That didn't stop the EPA from giving the green light in October 2010 to increase the ethanol in our national gasoline supply from 10% to 15%.

At the E15 announcement, Secretary of Agriculture Tom Vilsack unveiled a $461 million program to pay up to 75% of farmers' costs in growing and harvesting biomass for use in nearby cellulosic ethanol plants; funding for 10,000 new ethanol fuel pumps at a total cost of $250 million; and a call for sufficient federal assistance to build at least one new cellulosic ethanol plant in each region of the country in 2011.

Lobbyists and special interests aside, DeCicco says there is one type of biofuel still worth considering: fuels made from wastes that would otherwise be discarded, namely biodiesel. "That's good news for the home-brew energy crowd," says DeCicco. "If you brew it yourself from stuff that would've gone to waste, then it can be a net gain for the environment."

Homemade biofuels made from locally sourced waste vegetable oil or other feedstocks are a viable but small part of the alternative fuel solution. Below, biodiesel produced from used cooking oil (left) and virgin canola oil (right).

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Craig Reece agrees. He is the owner of Berkeley, California-based PlantDrive, one of about a half-dozen companies that makes kits to convert diesel-engine cars to run on filtered, discarded vegetable oil.

Reece is also a vocal advocate of producing biodiesel from waste vegetable oil (WVO). "That oil was already used for making french fries by the time we get our paws on it," says Kumar Plocher, president of Yokayo Biofuels in Ukiah, California. His company is basically in the recycling business—collecting WVO from more than 1,100 restaurants in Northern California, processing it into biodiesel, and delivering it back to local users.

"I think that biodiesel, particularly if it's made from waste vegetable oil instead of virgin soy, is very viable," Reece says. If you get a diesel-engine vehicle and run it on biodiesel made from waste vegetable oil rather than virgin soy, you're doing a whole lot for the planet, probably more than somebody driving a hybrid."

Reece argues for those people who don't want to spend $20,000 or $30,000 for a brand new EV, but who have time to pick up discarded restaurant oil and filter it, saying they "come out way ahead." With the recent jump in fuel prices, there's more competition for restaurant oil, but there's still plenty to go around because of the economic recession. "There are fewer players now, because 2010 shook out a number of biodiesel companies," Plocher says.

Even with an electric car, consumers still have to pay for electricity. WVO can often be obtained free from a local restaurant. "There's just something about driving for absolutely nothing, other than a little sweat equity," says Reece. "I love driving for free [and] beating the system."

Access

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PV Module Lift

Build ~~Do~~ It Yourself

Story & photos by Ken Gardner

The author places the pulley support on top of the ladder.

Getting PV modules from the ground to the roof can be a back-breaking job. Modules that are being installed on sloped roofs are usually raised one at a time and then fastened to support rails, making installations slow and tedious. For small residential systems on low roofs, a typical method of conveying modules to a rooftop is to push them a short distance up a ladder to someone waiting above, but this method is impractical and unsafe. Mechanized lifts can be rented, but rates can be expensive enough to push a DIYer's budget over the edge.

One Back-Saving Tool

To remedy this problem, I developed an inexpensive and simple means to transfer modules to the roof. It can be built in a few hours by anyone who has basic construction skills, and materials cost between $45 and $80. (Although I used scrap strut pieces, strut can be purchased in 10-foot lengths from most home improvement stores.)

The lift is constructed of common building materials—lumber, pulleys, and rope—available at hardware stores. As designed, it collapses to less than 9 feet for easy transport and storage. The concept can be adapted to most module-hoisting needs.

The lift consists of two parts—the framework to which the module is secured and the top-of-ladder pulley support. The lift uses the mechanical advantage of two simple pulleys, rated for 100 pounds each, and relies on simple physics. With the pulley system, the force needed to lift a PV module is half

The secured module is hoisted from the ground to the crew on the roof.

the module's weight. A 180- to 200-watt module typically weighs 40 to 50 pounds, so the force needed to lift the module will be 20 to 25 pounds.

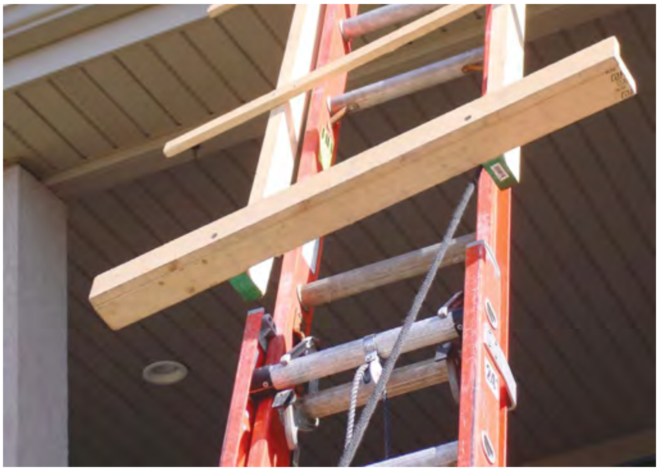
The framework resembles a simple ladder, with a pulley attached at the top of the wooden frame. The wooden framework slides along the outside of the extension ladder's rails. However, with extension ladders, the upper section usually sits above the lower section, creating a barrier to sliding modules smoothly up the ladder. Solving this problem is as simple as rotating the ladder 180° from front to back, which then permits the transition from the lower to upper section to become a landing.

The size of the framework depends on the size of modules being lifted. The lift we built can handle a single module up to 47 inches wide and 66 inches long. A protruding wooden lip at the frame's base secures the module against the framework. At the top of the frame, a 1-inch-wide canvas strap holds the module in place as it is lifted to the roof.

The upper pulley support was made from strut and strut fittings as shown, but other means to support the pulley at the top of the ladder are possible. Strut fittings are connected with 3/8-inch bolts and standard strut cone nuts or springnuts. The pulley support at the top of the wooden support frame is attached to a scrap of 3/4-inch-plywood, which is stronger than most dimensional lumber.

Design Tweaks & Lift Tricks

- Make sure the vertical rail components extend about 4 inches below the framework's wooden lip—otherwise, the support tends to catch on the ladder foot supports.
- Be sure to countersink all screws so that they will not be able to come into contact with the module glass.
- Knots can be placed in the lifting rope on approximately 4-inch centers to help stop the rope from slipping through lifting hands.



As the lift returns down the ladder, use the rope to lift the bottom edge of the framework over the lower ladder extension.

Parts List

Wood Frame Module Support

15 ft. 7 in.—2 x 3 in.; cut to (2) 5 ft. 10 in. pieces for uprights and (1) 3 ft. 11 in. piece for bottom horizontal

3 ft. 11 in.—1 x 4 in. for top horizontal

3 ft. 11 in.—3/4 x 3 in. cabinet-quality plywood for frame lip

7 ft. 10 in.—1 x 2 in.; cut to (2) 3 ft. 11 in. pieces for middle horizontals

2 in. wall-mount pulley

(8) 1/4 in. self-locking nuts and washers

65 ft. of 3/8 in. polypropylene or nylon rope (for 24 ft. ladder)

(4) 1 1/2 in. “Grabber” screws

(2) 1 in. wide x 18 in. long hook-and-loop straps

(2) 1/4 x 3 1/2 in. carriage bolts

(2) 1/4 x 6 in. carriage bolts

(4) 1/2 x 1 in. bolts (to attach pulley and straps)

Top-of-Ladder Pulley Support

2 in. wall-mount pulley

6 ft. 2 in. of 1 5/8 in. deep strut

(2) 1/4 x 1 in. bolts

1/4 x 1 in. eye bolt

(3) 1/4 in. strut cone nuts or spring nuts

6 L-strut brackets

(2) 90° strut brackets

(3) 1/4 x 1 1/2 in. fender washers

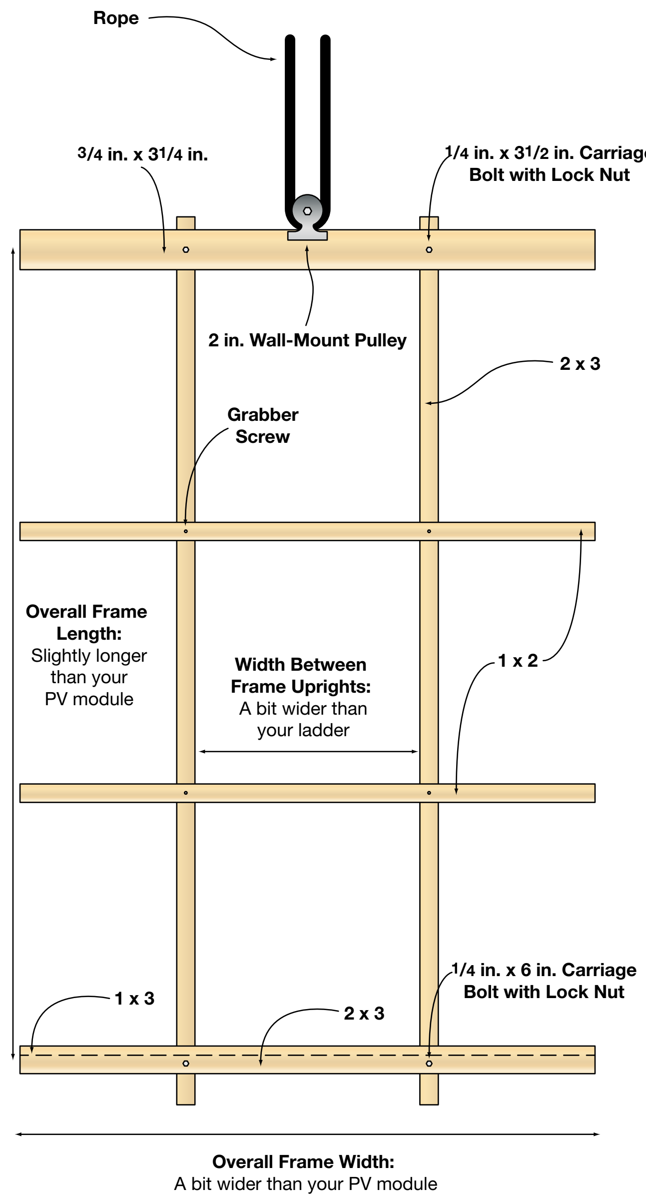
(20) 3/8 x 1 in. bolts

(16) 3/8 in. strut cone nuts or spring nuts

(4) 3/8 in. lock nuts and washers

6 deep strut end caps

Lift Framework Details



Rigging the Lift

The ladder is first set against the roof eave. Next, the upper pulley support is placed on top of the ladder and the rope tied on the eyebolt adjacent to the pulley. (Note: Be sure to use an appropriate knot that will not self-release under any circumstance.) The wooden support frame is then placed on the ladder; the rope is placed through the pulley on the support, routed back to the upper pulley, and then extended behind the ladder to the ground. The module is set behind the wooden lip at the base of the frame and then secured at the top by the canvas strap. One person is on the ground, securing and hoisting modules, while the rooftop person removes the module from the frame after it arrives at the top.

Once the module is lifted to the roof and removed from the frame, the frame is lowered back to the ground. During lowering, the transition between the two ladder sections

The author collapses the lift for transport.

Mechanized Lifts

Mechanized lifts using gas or electric-powered motors have been developed for the roofing industry and have been adapted for the solar industry. However, the lifts are usually large—sometimes large enough to require an additional truck to haul it to the site. Their greatest value comes when many modules need to be lifted. The TopLift Eco ($5,900, by Boecker USA; www.boeckeramericas.com) is one option specifically marketed for PV modules. It can hoist up to 330 pounds to 67 feet, and its drive unit weighs 104 pounds.

becomes a barrier. The rope normally used to raise and lower the *ladder* sections can be used by the person raising the modules to lift the wooden frame over the ladder transition. Using the ropes to pull the bottom of the support rack is easy when the rack is coming down empty.

Access

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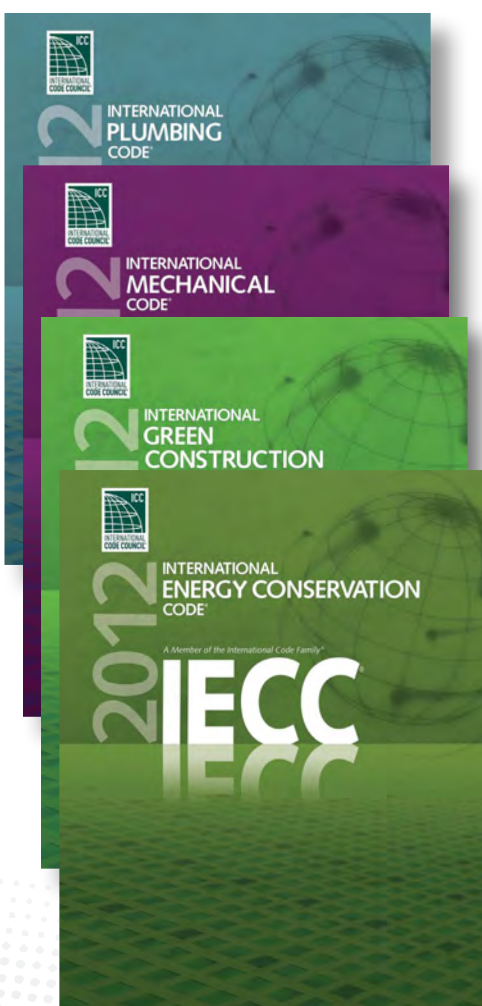
Codes & Certifications for Solar Hot Water Systems

by Chuck Marken



Building trades code books have a history of being difficult to understand. Sometimes, instead of a reference on how to do things right, they can seem more like codes used to send secret messages. And if you don't know the key, the information can be obscure or undecipherable. Confusion and conflict are often the result of different interpretations.

SHW code books are getting better, but they are not without their failings. In addition to a bunch of codes, there are also certifications for solar collectors, systems, and installers—and where do these fit in the industry?

Here are some insider insights and background on codes and certifications most applicable to SHW systems.

Why Codes & Certifications?

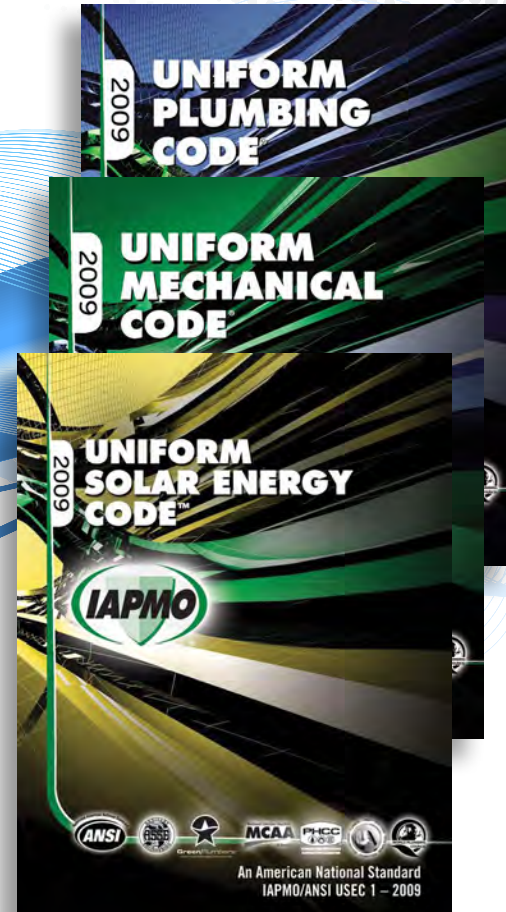
Codes are published and enforced for the health and safety of the public. They specify acceptable materials, sizes of materials, and other information for constructing safe buildings and the electrical, mechanical, and plumbing systems within. Plumbing, heating, cooling, and solar codes are usually published by two national code-writing organizations, but sometimes local government agencies write their own codes.

Whether a government writes its codes or adopts those written by someone else (as most do), they have the rule of law behind them. Government agencies regulate the building trades through building permits, code enforcement, and licensing qualified individuals and companies.

In the United States, each state administers its code enforcement and licensing. Many large municipalities have additional code requirements instead of or in addition to state requirements. The codes used, and licenses and permits required, can change significantly across state lines. Licenses in most trades are only recognized in the state of issue.

Wading into the Alphabet Soup

In the United States, *five* code books give guidance for installing solar water heating systems. The International Code Council (ICC) publishes the *International Plumbing Code* (*IPC*) and the *International Mechanical Code* (*IMC*). The International



Association of Plumbing and Mechanical Officials (IAPMO) publishes the *Uniform Plumbing Code* (*UPC*), the *Uniform Mechanical Code* (*UMC*), and the *Uniform Solar Energy Code* (*USEC*).

The books are published on a three-year cycle, with the most recent being the 2009 version. The ICC codes are used in the majority of the U.S. states, especially in the East and Midwest, but there is no precise dividing line where the different books are used—it all depends on the jurisdiction.

Having two sets of published codes for the same trade is a hassle. If you move across a state line, or even into another local jurisdiction, you may find yourself under a different set of rules—although they are similar, the nuances can be nuisances. It is also a reason why plumbing and HVAC licenses don't have reciprocity like the electrical trades with a single national code.

There may come a time when the United States will have a single set of code books for solar water, pool, and space heating. The ICC codes seem to be gaining ground. It could be that their books are easier to read and understand, or that the *International Energy Conservation Code* gets a push from the government.

The USEC

The *IPC* and *UPC* are the senior references for all issues dealing with potable water, and specify materials and other requirements for supply piping systems. Likewise, the same is true for heating and cooling systems with the *IMC* and the *UMC*. For solar thermal systems, however, the plumbing and mechanical code books don't offer much specific detail, and that's where IAPMO's *Uniform Solar Energy Code* (*USEC*) steps in.

Until recently, the little-known *USEC* has not been widely adopted. However, the 2009 edition was adopted as a standard by the American National Standards Institute (ANSI), which publishes standards for almost everything. (For instance, if you want the specifications and standards for a certain kind of bolt, ANSI is the place to look.)

The *USEC* specifies materials for collectors and balance-of-system components. The 88-page book covers material specifications and some design and installation requirements for collectors, tanks, heat exchangers, piping, insulation, and more.

Conflicts & Controversy

Compared to the faster-paced PV industry, the thermal industry has a snaillike pace of innovation. For the most part, SHW installers are installing the same basic types of systems they did 30 years ago. Although this makes the industry seem stagnant, the reality is that flat-plate collectors are simple devices that already approach maximum theoretical efficiency. Except for improved longevity, collector technology hasn't changed in decades. Strides in lowering costs, and overcoming fragility and longevity issues are being made for evacuated-tube collectors, but, again, the systems are nothing new.

Heat exchanger design has been the only big change in the last few years. The ICC and IAPMO books are now in relative agreement when it comes to heat exchangers—and this is a first. Both the *IMC* and *USEC* now allow single-wall heat exchangers with nontoxic heat-transfer fluid; the *USEC* also requires a pressure-relief valve of no more than 30 psi if a single-wall exchanger is used—probably because the pressure-relief will actuate below the municipal water pressure.

Handy Definitions

Authority having jurisdiction (AHJ)—An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.

Potable water—Water for human consumption.

Mechanical systems—Heating, ventilation, air-conditioning, and refrigeration (HVAC-R) equipment.

Journey-level plumber—A licensed plumber usually requiring at least two years of experience and passing at least one exam, sometimes both a written and hands-on exam.

Master plumber—Normally, a licensed plumbing contractor who can bid jobs. Becoming a master plumber typically requires at least four years of experience and passing at least one exam—sometimes a plumbing code exam and a business and law exam.

Specialty solar license—A limited license used in some states to allow individuals and contractors to work on, for example, only solar water and pool heating systems.

The ICC's *IMC* was the first to allow single-wall heat exchangers, while the *UPC* and *USEC* required double-wall, vented heat exchangers if a system design calls for anything but potable water in the collector loop.

This requirement made even nontoxic-antifreeze-based systems that have less-expensive and higher-efficiency single-wall exchangers illegal in those jurisdictions using the *UPC* and *USEC* and subject to a red-tag correction notice—essentially a notice that work or use must be stopped because of unsafe conditions.

Now, a change in the 2009 *USEC* allows single-wall exchangers, so long as the collector-loop pressure relief is a maximum of 30 psi and a caution label is provided to warn of the fluid in the system. The 30 psi relief provision stems from municipal water systems, which typically have higher pressure than that. The logic is that any leakage will travel from higher to lower pressure.

However, not all jurisdictions are on board. The health department of Louisiana, for instance, believes that single-wall exchangers are not fail-safe enough to prevent municipal water supplies from being contaminated by a leaking system with the wrong (toxic) antifreeze installed. While health officials also were skeptical of double-wall exchangers, they appeared to see the logic that it was impossible for a system with a double-wall exchanger to threaten city water systems. The department's solution is to require backflow preventers on any building where a SHW system is installed. This decision may also require hiring qualified people to check the backflow preventers at least annually. The irony is that these costs make installing systems with single-wall exchangers more expensive than ones with double-wall exchangers.

Codes & Installing Your Own System

If you are installing a SHW system in any jurisdiction using ICC code books, the 132-page *IMC* is the book you that will be the most valuable to you. The *IMC* contains a small section on boilers and water heaters in Chapter 10 and two pages on solar systems in Chapter 14, which also has a paragraph on heat exchangers in Section 140. Reading all this takes less than a half hour.

The *IPC* addresses rules regarding potable water and waste systems. Most of what might pertain to a SHW system is in Chapter 6: Section 607 (Hot Water Supply Systems) and Section 608 (Protection of Potable Water Supply). The *IPC* also has rules for heat exchangers that are a little different than the *IMC* and are in Section 608.16.3. It just takes a short time to read these sections in their entirety.

The difference in the code publishing organizations is evidenced by the ICC putting water heaters in the mechanical code book and IAPMO putting water heaters in the plumbing code book. In the *UPC*, Chapter 5 (Water Heaters) and Chapter 6 (Water Supply and Distribution) provide guidance for SHW systems. Heat exchangers are redundantly addressed in the IAPMO books with Sections 506.4.2 and 603.4.4.1 in the *UPC*, and Section 405.1 in the *USEC*.

In IAPMO jurisdictions, the *USEC* is usually the governing code book, but this, as in all things relating to codes, is up to the individual location. This book contains more detailed information about SHW systems than the ICC books. The first three chapters of the *USEC* are just the standard boilerplate of administrative procedures, definitions, and regulations common to all code books. But, even here, the detail about SHW systems is evident in that definitions are given for things like drainback systems, closed-loop, collector tilt, and many other terms that are not given in the *IMC*'s definitions.

Here's a breakdown of pertinent SHW section in the 88-page *USEC*:

- Chapter 4—Piping (includes heat exchangers)
- Chapter 5—Joints and connections
- Chapter 6—Thermal storage (water storage and expansion tanks)
- Chapter 7—Collectors (materials suitable for liquid and air collectors)
- Chapter 8—Insulation (pipe and duct insulation)
- Chapter 9—Ductwork (a single sentence; it just gives reference to the *UMC* chapter on ductwork)
- Chapter 10—Electrical (This chapter is sometimes not adopted by jurisdictions since it is just a copy of the *National Electrical Code*'s Article 690, which local building officials have probably already adopted.)
- Chapter 11—Material standards (10 pages of references on standards for piping, etc.)

Many sections of the *USEC* refer back to the *UPC* or *UMC*, as does the whole of Chapter 9. These references have little to do with an SHW installation. Keep in mind, the authority having jurisdiction (AHJ or "inspector") is the ultimate decision-maker of what is safe or not—and arguing with them may not be wise. However, if you have a justification for a component or technique in writing, inspectors' opinions can often be swayed.

I've noticed that inspectors often concentrate on two things: pressure-relief valves and heat exchangers. It makes sense because a pressure-relief valve on an antifreeze system will prevent excessive pressure buildup and a heat exchanger of the right type will prevent water supply contamination in the event the heat-transfer fluid is toxic. Public health and safety is the reason we have codes in the first place.

Beyond the Codes—Certifications

Certifications for collectors & systems. When energy conservation and RE tax credits hit the mainstream in the late 1970s, much SHW system marketing went over the top. This first tax credit era brought out the worst, with some fly-by-night manufacturers claiming outlandishly high SHW system performance. In addition, unscrupulous businesspeople wanting to cash in on the trend became inexperienced installers, installing substandard and shoddy systems. The newly established Department of Energy told the solar thermal industry to clean up the problems and threatened to have the government do the janitorial work if the industry hesitated. The Solar Rating and Certification Corporation was founded in 1980 as the solution. This nonprofit organization certifies solar thermal collectors and SHW systems based on testing by accredited independent test laboratories. The SRCC is funded partly by fees levied on manufacturers.

If you plan to take advantage of federal tax credits for SHW systems, the collector or system must be SRCC certified. Many state and utility incentive programs also require SRCC system certification for eligibility. The SRCC merges the system certification data with climate data for hundreds of locations in the United States to achieve fairly accurate estimates of system performance. Many incentive programs use these estimates to calculate system rebate amounts, since hot water isn't metered like electricity. Incentive program administrators like to base the incentive rewards on system performance as much as possible and the estimates are the next best thing to a meter.

You would think 30 years of history would mature an agency like this into a well-oiled organization. Not so. When the last federal tax credits were implemented in 2006, resulting in an onslaught of new SHW collector and system manufacturers, the SRCC was caught off-guard. Because it recognized the test results of only two laboratories, a two- to three-year backlog of certifying collectors and systems ensued. And, because a lack of a certification made a product ineligible for incentives, innovation and new product development was hindered. The backlog has diminished with the accreditation of many new laboratories last year. More information on the certifications is available at www.solar-rating.org.

Professional certification. The nonprofit North American Board of Certified Energy Practitioners (NABCEP) certifies installers in the PV, thermal, and wind industries based on passing a written exam. The thermal certification tests individuals on their knowledge of solar hot water and pool heating systems—in particular, safe installations. There are numerous tracks to be eligible to take the certification test, but all require candidates have a minimum of two documented installations. NABCEP has always had the policy of keeping the certification voluntary. With the bottleneck created by the SRCC, which was unable to quickly respond to a growth spurt, keeping the NABCEP certification voluntary seems

wise. Note that while the NABCEP certification can give consumers confidence in a contractor's technical expertise, the certification rarely takes the place of a license issued by the appropriate government agency.

Both the SRCC and NABCEP certifications are voluntary—up to a point. Uncertified collectors can be made, sold, and installed but the SRCC certification is required to receive the 30% federal tax credit. Plus, in many cases, the SRCC's more comprehensive system certification is required to take advantage of state and utility incentives. The NABCEP certification also is required by a few state and utility incentive programs, even though NABCEP has a policy of discouraging mandatory certification.

Related National Codes

The *International Energy Conservation Code* (*IECC*) is used to help calculate federal tax credits for energy-efficient homes and energy-efficiency standards for federal residential buildings and manufactured housing. The code has the support of the U.S. Department of Energy (DOE) due to the efficiency gains that the code promotes and relates to federal law through the Energy Policy Act of 1992. The DOE claims that the 2009 version will result in approximately a 15% improvement in residential energy efficiency compared to the previous edition. The IECC contains a small amount of information on solar thermal systems—it allows waiving the requirements for a pool cover if a solar thermal system provides 60% or more of the pool's heating. This code is downloadable at www.iccsafe.org/store/pages/doeregistration.aspx.

The 2009 *Uniform Swimming Pool, Spa and Hot Tub Code* published by IAPMO is also an ANSI standard. The code governs the installation, inspection, alteration, and maintenance of swimming pool, spa, and hot tub systems and their components. In 2009, the ICC announced it would publish the *International Swimming Pool and Spa Code* in 2012, and is working with the Association of Pool and Spa Professionals to develop the code.

Access

Contributing editor **Chuck Marken** (chuck.marken@homepower.com) is a plumber, electrician, and HVAC contractor licensed in New Mexico. He has been installing and servicing solar thermal systems since 1979. Chuck is a part-time instructor for Solar Energy International and the North Carolina Solar Center, and works under contract with Sandia National Laboratories supporting the DOE-sponsored Solar Instructor Training Network.

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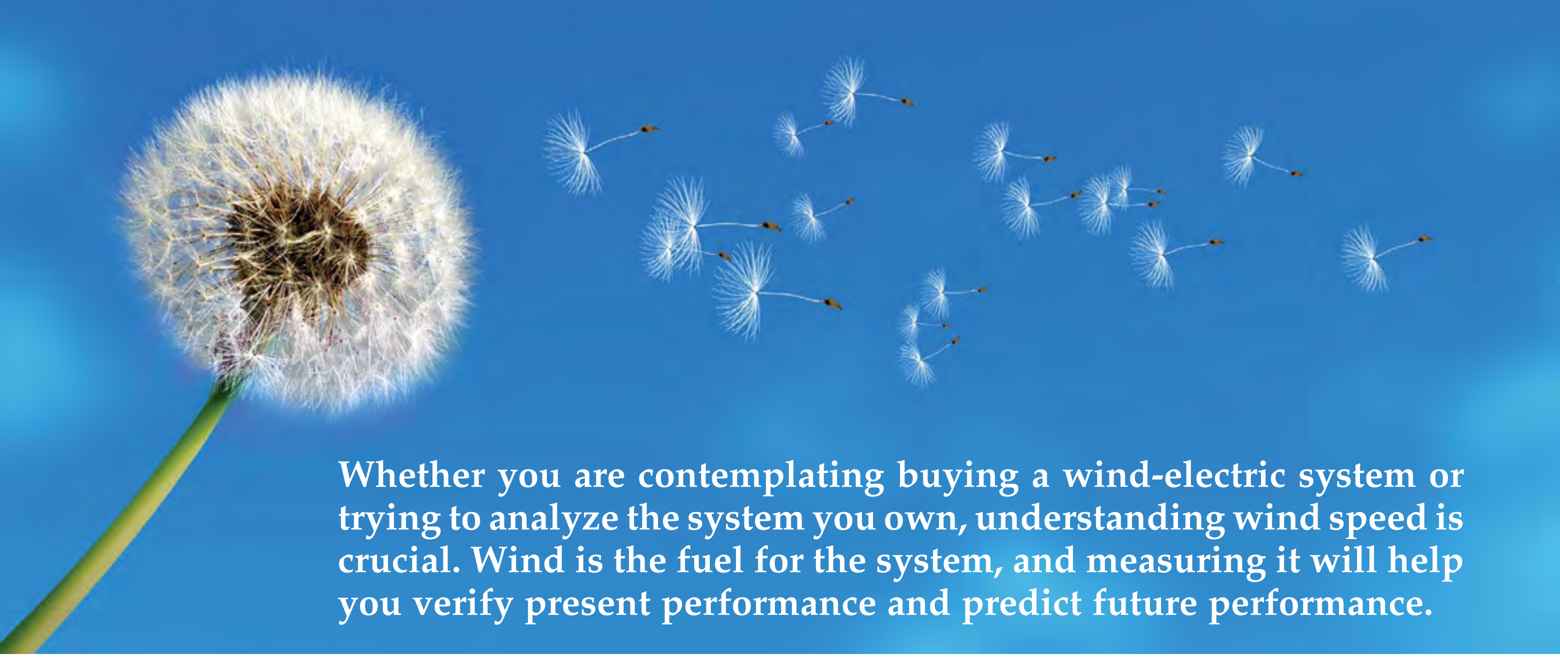
Understanding *Wind Speed*

by Ian Woofenden



Whether you are contemplating buying a wind-electric system or trying to analyze the system you own, understanding wind speed is crucial. Wind is the fuel for the system, and measuring it will help you verify present performance and predict future performance.

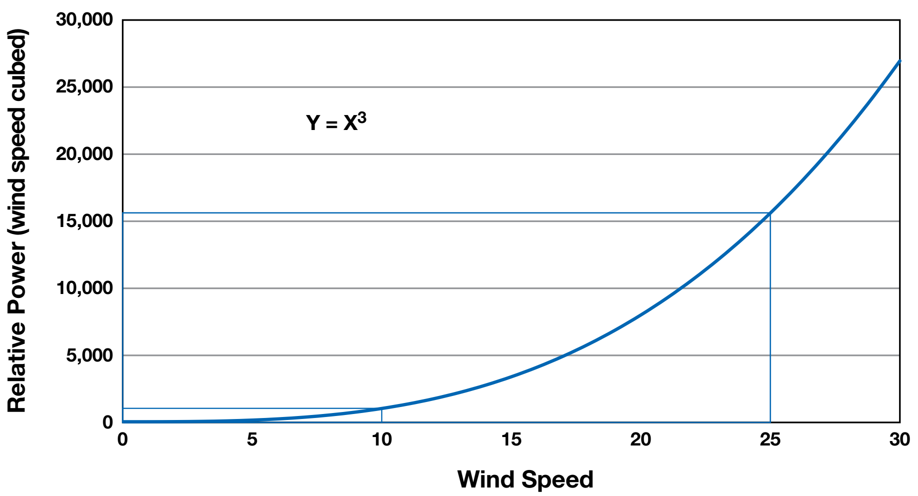
Differentiating between *instantaneous* and *average* wind speed is very important. These are two *very* different measures—as different as your average speed while driving between Philadelphia and Boston, and the (instantaneous) speed the cop caught you driving at on the New Jersey Turnpike. If you were going 78 mph when the radar hit your car, no amount of explaining to the cop that your *average* was 57 mph will let you escape that ticket.

With wind energy, instantaneous wind speed is the less important measure, and average wind speed steps into the primary position. For residential systems, the average wind speed at the tower top is the primary measure used to quantify the wind resource. Let's look at these two measures and the real-world ranges you will find.

Instantaneous

Recorded instantaneous wind speeds range from 0 mph (of course) to about 231 mph—the latter has been experienced at Mt. Washington, New Hampshire. Higher wind speeds likely have occurred elsewhere, but have not been measured. At typical home sites, winds might run up to the 70 mph to 100 mph range a few times a year. More normal instantaneous wind speeds top out in the 40 mph to 50 mph range. But for wind energy production, the important range of instantaneous speeds is between 10 mph and 25 mph. Why?

Power Relative to Instantaneous Wind Speed

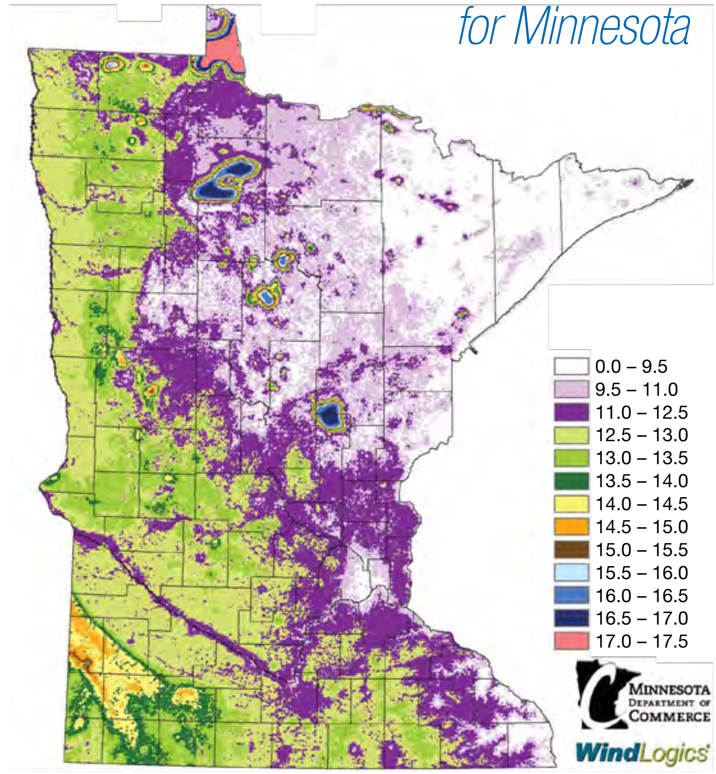


Below about 10 mph, there isn't a huge amount of energy available in the wind. Wind power is cubic—so assuming 1 mph produces 1 unit of power, a 10 mph resource will yield 1,000 units (10 × 10 × 10). At 5 mph—50% of that speed—you'll wind up with 125 units (5 × 5 × 5)—12.5% of the power in 10 mph winds. At the other end of the scale, 25 cubed—which is 15,625—represents a lot of potential energy, and a lot of force on your turbine and tower. Between 25 and 30 mph, most turbines worth buying start shedding wind in one way or another, to protect the machine. A machine built to generate reliably in higher wind speeds would have to be awfully beefy, and it would probably not perform well at the lower wind speeds experienced most of the time at most sites.

It is useful to know the typical high wind speeds at your site, since this will impact the strength and durability required of your turbine and tower. If your site rarely has 50 mph winds, you might be able to use a less-expensive, medium-duty turbine. A heavy-duty turbine is needed for sites that regularly experience 80 mph winds.

Instantaneous wind speeds are interesting to monitor, but beyond determining the stoutness of your turbine and tower, that data isn't very useful. The goal is not peak power (watts), or power at any particular wind speed, but energy (watt-hours). And to predict that, we need to use average wind speed.

Example Average Wind Speed Map for Minnesota

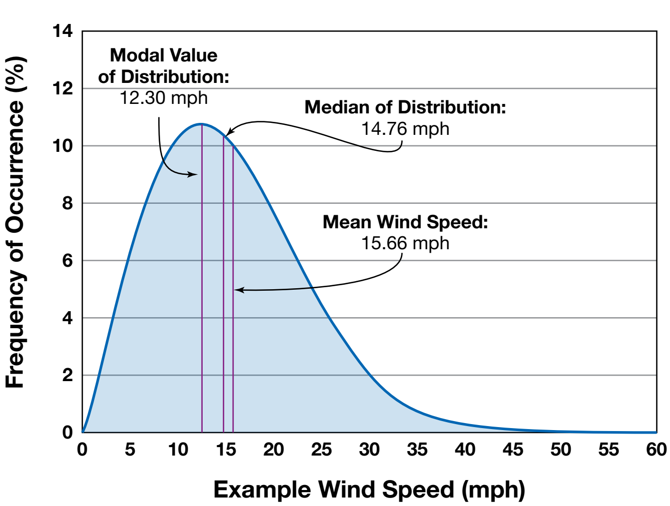


Average

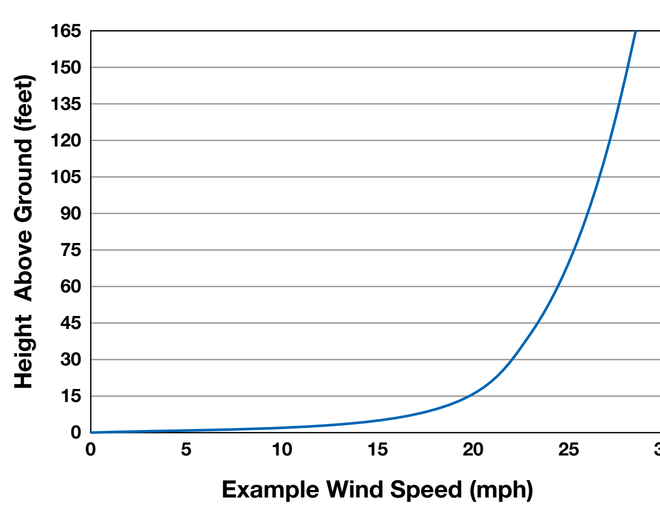
Average wind speed is calculated by measuring instantaneous wind speeds over time on a site, and averaging them (see Mike Klemen's nerdy article, "Wind Speed Data & Its Application to Wind-Generated Power," in *HP62*). Most sites suitable for home-scale wind systems lie within the 6 to 12 mph average range. For an on-grid household, a 6 mph site will not typically be cost-effective, but, if you're off-grid, it might be better than running your generator a lot in the winter. In most cases, a 12 mph site will make economic sense.

Utility-scale wind farmers are looking for even higher average wind speeds, in the 12 to 18 mph range. The highest recorded annual *average* wind speed is also on Mt. Washington, about 35 mph. But this is an extreme site, and most wind farms don't exceed the low 20 mph average. Those predicting or reporting higher averages are either looking at shorter-term averages (like monthly, not annual, averages), or they are blowing smoke.

Example Wind Speed Distribution



Example Wind Speeds at Heights



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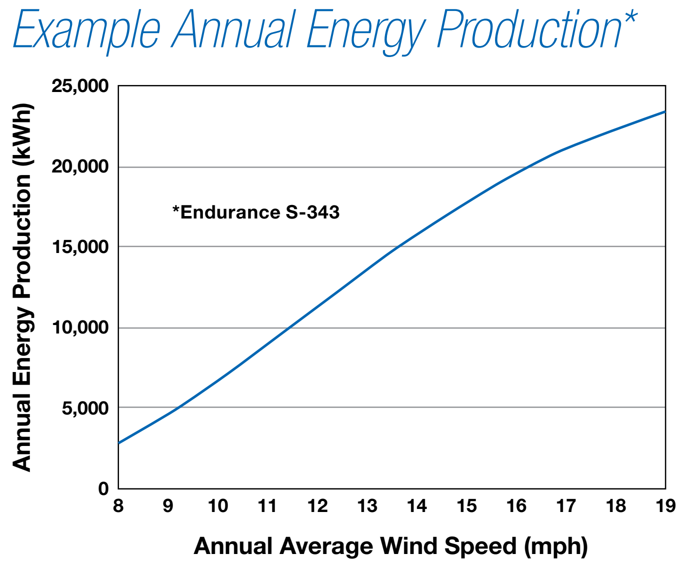
An anemometer is one tool for measuring wind speed, but how the data is logged, averaged, and interpreted is more important for determining wind energy potential.



We use the average wind speed to predict wind generator production by looking at manufacturers' energy curves (see example), looking at certification data, or using formulae (see "Estimating Wind Energy" in *HP102* for one example). Average wind speed is to wind generator production what peak sun-hours are to solar-electric production.

Understanding

To help avoid unrealistic expectations, I suggest that you:

- Clearly understand the difference between instantaneous and average wind speeds, and realize that the latter is most important.
- Understand that instantaneous wind speeds have lesser value, since the wind varies and the power available varies cubically with wind speed. Knowing a specific instantaneous wind speed only gives us one point of data, which is just as useless as one point in the power (kW) curve.
- Understand the realistic range of average wind speeds on residential sites, and try to ascertain the average wind speed at turbine height on your own site. This number is the most useful in predicting energy (kWh) output.

Access

Ian Woofenden (ian.woofenden@homepower.com) lives off-grid with an average wind speed of 7 mph. While not remarkable, it saves lots of generator run time, fuel, and racket. His wind turbines see 60 to 70 mph a few times a year, and have experienced 100 mph at least once in 25 years of providing wind energy for his home.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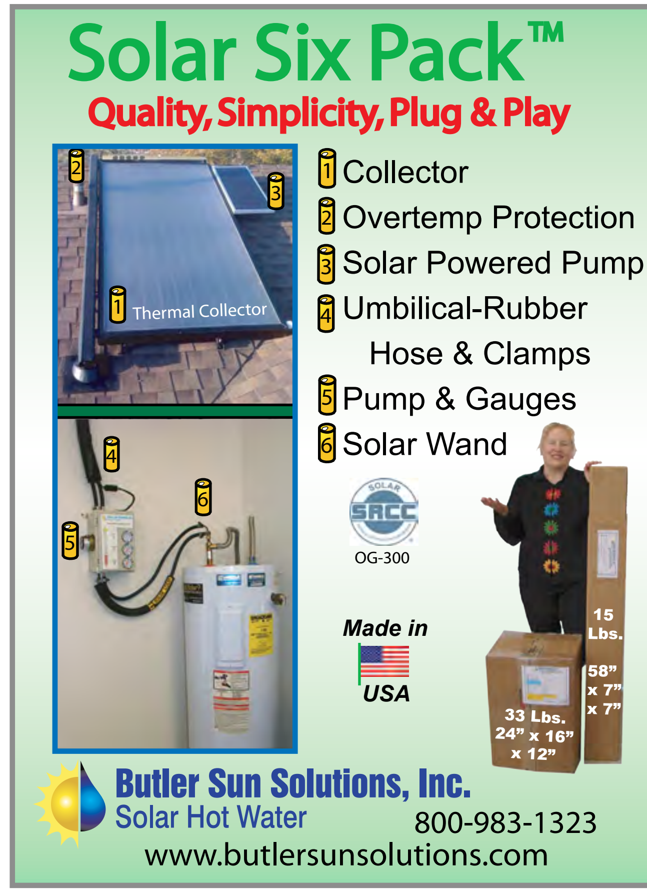
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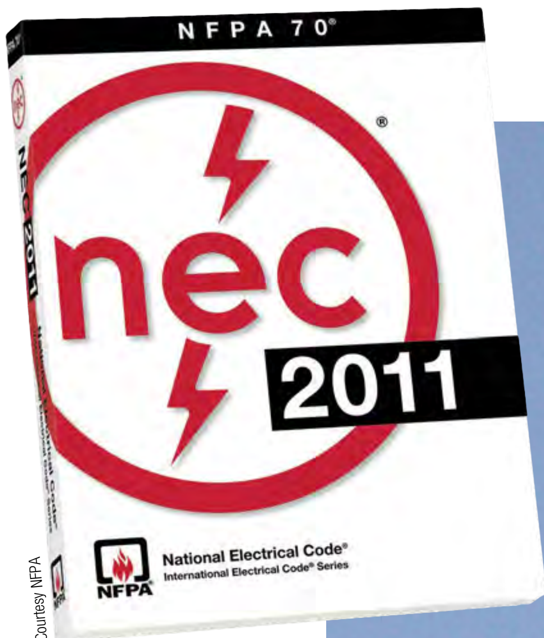
Small Wind Systems & the *NEC*

by Robert Preus



Courtesy NFPA

Courtesy Ian Woofenden

Move over, solar electricity: This year, small wind-electric systems got their own article in the *National Electrical Code*.

The *National Electric Code (NEC)* is a set of rules for the electrical connection and installation of all kinds of electrical equipment, but has lacked specificity for small wind systems (wind turbines rated at 100 kW or less)—until now. In the mid-1980s, PV systems were given their own presence in Article 690 of the *NEC*. Three decades later, small wind systems have earned their own Article—694—too.

In the past, due to the unique character of small wind installations, applying some of the general code was difficult or confusing, and AHJs often attempted to use the PV Article 690 to deal with this. However, PV can be disconnected from the load or short-circuited with no harmful effects. Some wind generators can also—but some cannot. This can result in unsafe conditions when applied to a small wind installations.

Getting to Wind

PV code pioneer and electrical engineer Robert Wills and I were persuaded to co-chair a group of wind industry stakeholders in developing a proposal to amend the 2008 *NEC* for its revision in 2011. In March 2008, we formed a stakeholder group that included input from about 50 participants, including installers, system designers, manufacturers, and incentive program managers with an interest in the small wind industry. The proposal had to be submitted using the rules of the *NEC* style guide. Wills was very familiar with these guidelines since he had been involved in the PV code from the beginning.

In January 2009, the 19 *NEC* code panels met to review and report on the proposals. Wills served as a delegate and I was an alternate. Literally hundreds of amendments to

articles covered by this panel were considered, debated, and voted on. They ranged from our group's proposal for a separate wind article to minor changes in wording of already-existing articles to improve consistency in the formatting and style. The separate article was accepted in principle with the requirement for some modifications, and assigned its own number—694.

In July 2009, the proposals by the panels were published, and the public comment period began. During this period, anyone with interest could comment on any of the proposed actions or changes to the *NEC*. If a proposal was rejected for lack of justification, the author or anyone else could provide justification. If someone objected to a proposed change that was accepted by the panel, they could submit an objection with justification for the objection. The panel responded to all comments.

In December 2009, the panels met to consider the comments and finalize their actions on each proposal. At that point, the new wind article was approved with modifications. The final, official adaptation of the 2011 *NEC* occurred at the June 2010 annual meeting of the National Fire Protection Association (NFPA), the organization responsible for the *NEC*. In September 2010, the 2011 *NEC* rolled out. Some jurisdictions adopt the new version of the *NEC* immediately; some wait longer or make their own modifications. But even if a jurisdiction has not fully adopted a newer version, sometimes parts of the latest versions are allowed or applied.

The process for addressing changes for the 2014 *NEC* will begin again in October 2011. There will be many proposals for modifying the small wind article since it is now included in the code. Many of the proposals will involve consolidation of requirements common to PV, wind, and fuel cell systems into Article 705; battery-related requirements will be consolidated into Article 480.

Section by Section

The format for Article 694 is modeled after the PV code's Article 690. Section I (694.1 through 694.7) establishes the scope of the article and provides definitions for terms specific to small wind systems. It also states that 694 requirements apply anytime they differ from the rest of the code—except for 705, when a small wind system is operated in parallel with primary sources of electricity; and 500 through 516, when a system is installed in a hazardous location.

Section I specifies that small wind systems shall be installed by qualified persons. This issue caused great debate between those who think that the *NEC* should specify only *how* the installation is done—and not by whom. Section I also requires surge protection between the wind turbine system and the loads served, and allows standard plug-in receptacles on the wind turbine branch or feeder circuit for maintenance or data acquisition. (This is not allowed for in PV systems under Article 690.)

Section II (694.10 to 694.18) covers circuit requirements. It defines how to calculate voltage and current for small wind systems and how to derate conductors. 694.15 covers overcurrent protection and, in an exception, does not require overcurrent devices when the conductors' ampacities (sized in accordance with 694.12(B)) exceed maximum current from all sources.

Section III (694.20 to 694.28) relates to disconnecting issues. Section 694.20 provides an exception that exempts a wind turbine that uses an output circuit for regulating speed from having a disconnecting means. Section 694.24 allows a shorting switch or shorting plug to be used as an alternative to a disconnect in this case. This makes sense with the understanding that a small wind turbine is a limited current source and that, for some small wind generators, disconnecting the load produces a dangerous situation. This is one of the prime reasons that small wind needed its own article. Section 694.22 (D) allows the installation of rectifiers, controllers, and inverters in nacelles (wind turbine housings) and other exterior areas that are not readily accessible.

Section IV (694.30) covers wiring methods. It requires that flexible cords comply with Article 400 and be identified as hard service cord, listed for outdoor use and water-resistant. DC output circuits in a building must be in metal raceways, from the point of penetration at the building's surface to the first readily accessible disconnecting means.

Section V (694.40) addresses grounding. It requires that towers and turbine nacelles be attached to an equipment grounding conductor, but exempts attached parts, such as tails, that have no energizing source. Guy wires are not required to be connected to the equipment grounding conductor. Auxiliary electrodes and equipment-grounding conductors are both required for the tower structure. It refers to Article 250, Section III, for most of the details of the grounding requirements.

Section VI (694.50 through 694.56) prescribes signage that is required for various system configurations. It covers grid-interactive systems and stand-alone systems.

Section VII (694.60 to 694.68) pertains to connecting the system to other sources of electricity. This section requires that inverters used in grid-tied systems be listed and identified as utility-interactive, and that these systems comply with article 705. Section 694.66 allows inverters on branch circuits to exceed the normal voltage operating range so long as the voltage at the distribution panel remains within the normal limits. The reason that this is important is this: When inverters are pushing power into the grid, they raise the voltage to do so. If there is a long wire run between the inverter and the utility transformer, it is common to raise the voltage higher than the voltage allowed for the utility. Without this option, wind system owners would be required to install larger-gauge wire to limit the voltage rise.

Section VIII (694.70 to 694.75) covers storage batteries, referencing Article 480 for general battery requirements. But 694.70 spells out the current limiting and other battery-specific safety measures that are required, with an emphasis on systems at 48 volts nominal or greater. Section 694.75 also details requirements for charge controllers. One significant requirement is that a single diversion load control cannot

Courtesy Endurance Wind Power

Article 694 of the *National Electrical Code*, which covers wind-electric systems, will provide more consistency in system installations, and reduce the incidences of contractors and authorities having jurisdiction applying different code interpretations to installed systems.

be the sole means of regulating battery charging. A utility-connected service does not qualify as a reliable diversion load to meet the second regulating means requirement.

Section IX (694.80 and 694.85) is for systems greater than 600 volts. While there are few, if any, systems in excess of 600 V and, as far as I know, no battery systems over 600 V, serious efforts are made to not have the code limit future developments. So there are avenues left open that are not currently used. Section IX references Article 490 for general requirements, and also establishes the basis for determining battery and other circuit voltage for wire and device ratings.

What's Next

Some AHJs consider the wind turbine alternator as an AC source and are requiring grounding of the center of the three-phase wye for the alternator wiring, under Article 250.20. This does not work for a system that rectifies the output of the alternator and that has one leg of the DC bus grounded. You get a built-in short circuit load that keeps the wind turbine from starting. As 694 is applied, other areas in the code may require clarification as well.

The Code & Consumers

Article 694 for small wind-electric systems provides more consistency in their installation. There will be fewer surprises caused by contractors and authorities having jurisdiction applying different interpretations of the *NEC* for wind turbine system installations. Code-compliant systems also help guarantee that installations meet current safety standards.

Access

Robert Preus (robert@artre.us) is a wind energy systems engineer with experience in managing systems design for small and intermediate wind generators. He is also experienced in obtaining certifications, and in listing and marking wind energy equipment. Robert offers small wind technology training and engineering consulting in small design and certification through his company, Advanced Renewable Technology.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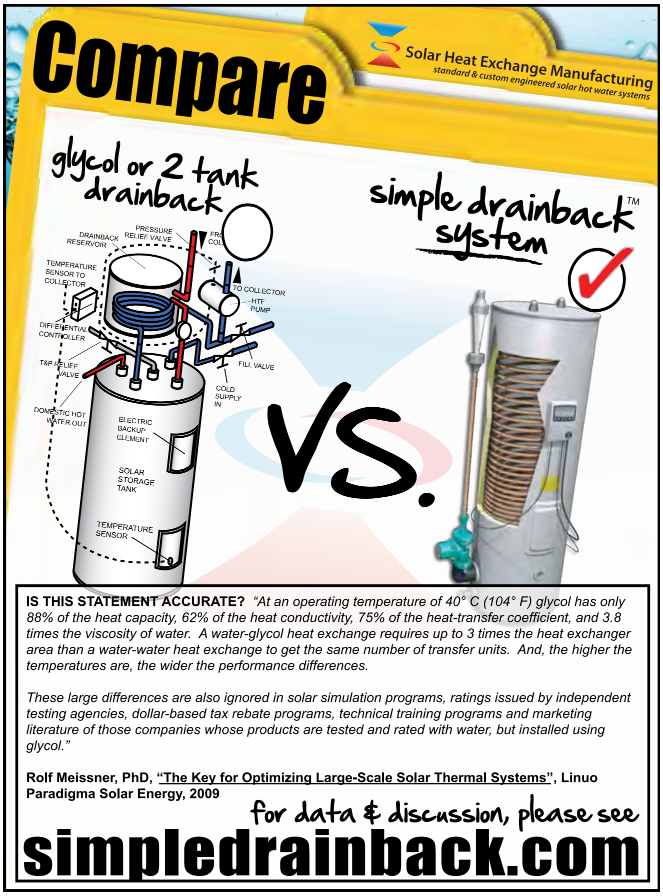
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These large differences are also ignored in solar simulation programs, ratings issued by independent testing agencies, dollar-based tax rebate programs, technical training programs and marketing literature of those companies whose products are tested and rated with water, but installed using glycol."
Rolf Meissner, PhD, "The Key for Optimizing Large-Scale Solar Thermal Systems", Linuo Paradigma Solar Energy, 2009
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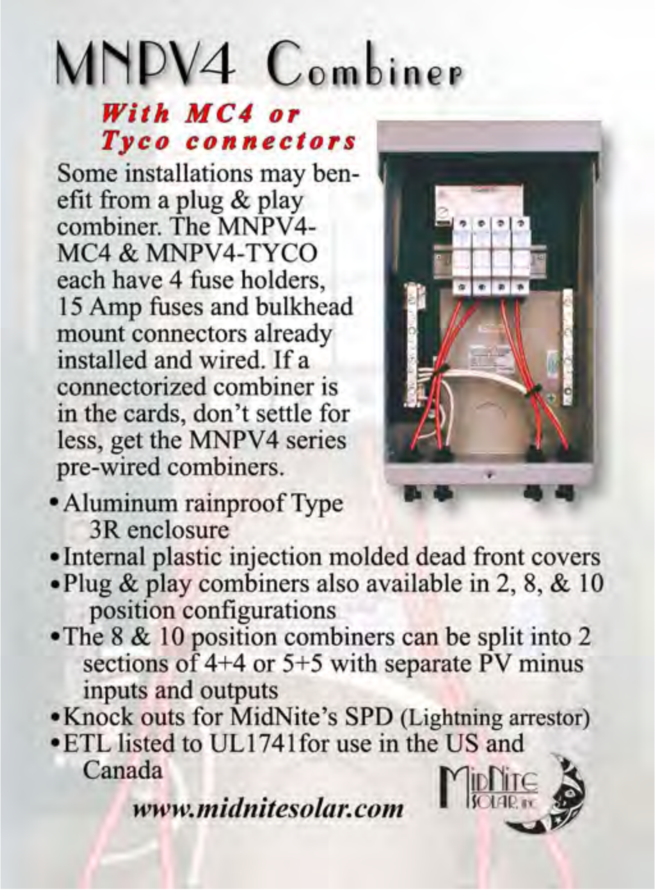
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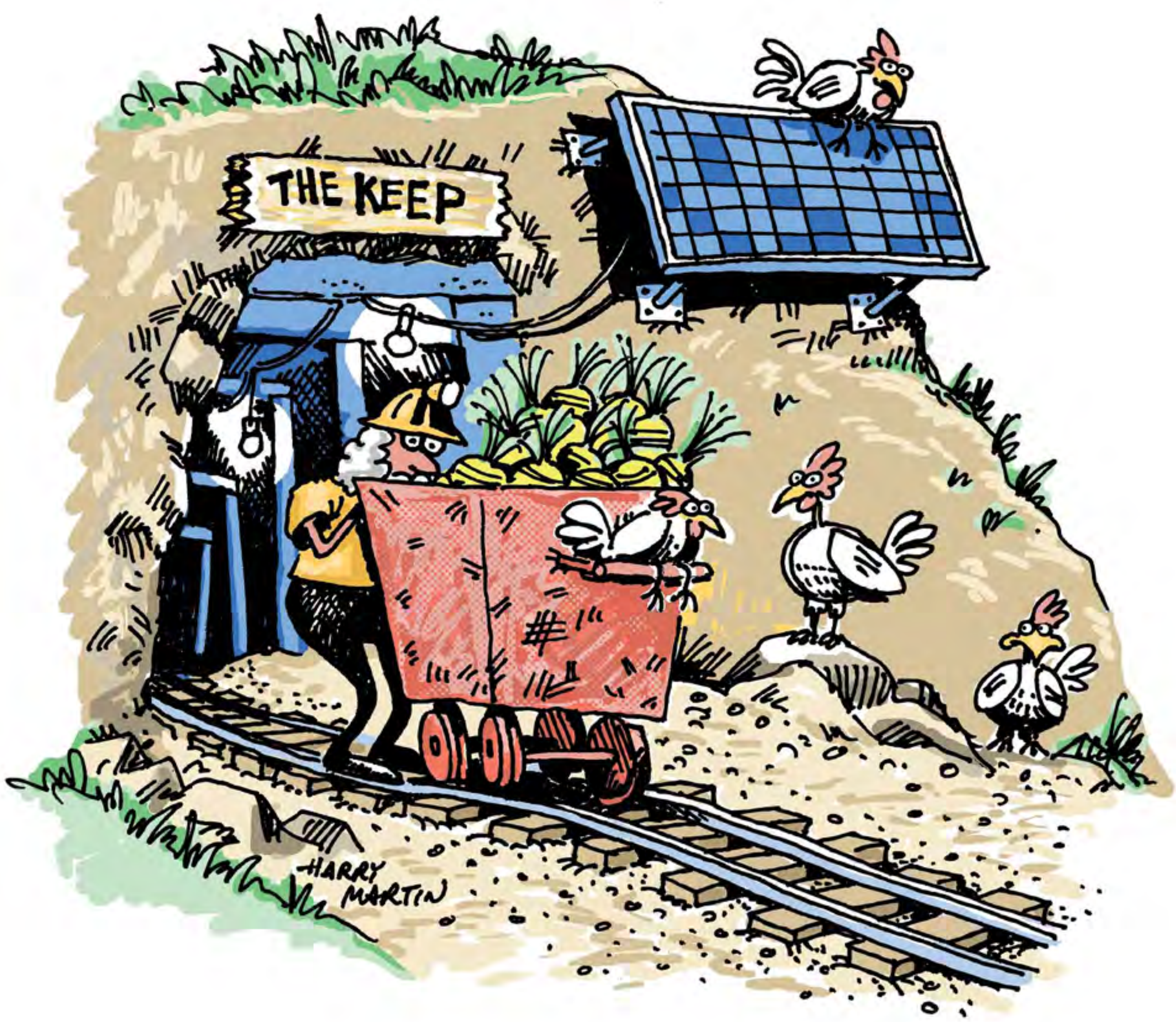
Backtracking

by Kathleen Jarschke-Schultze



I never quite know what topic will stir my readers to respond, but two recent topics garnered quite a few responses—"Zombie Containment" (*HP140*) and "Home on the Range"(*HP141*).

Keeping On

My husband Bob-O and I have passed a winter with our earth-sheltered, 20-foot-long steel cargo container. Dubbed "The Keep," its gleaming stainless steel shelves now hold canned and home-canned food, dry goods, onions, potatoes, and empty canning jars, with a few miscellaneous items thrown in for good measure.

The temperature in The Keep has ranged from 65°F to 41.5°F (the latter when the temperatures outside dropped to the single digits). Humidity fluctuates between 40% and 65%. I decided to use my basement pantry exclusively for wine storage, since its temperature varies by less than 10°F.

But our potatoes and onions have never stored so well as in The Keep. As I write this in March, we are still eating our garden-grown onions, potatoes, and carrots. They like dark, real dark, and cold. I tried to store green tomatoes to let them ripen off the vine. What seemed like a good idea at the time had a tragic and compostable end.

Our last frost date is a month behind many regions' dates. So I'm keeping my bare-root blueberry bushes dormant in The Keep until the right time arrives to plant them.

To answer some of the questions I received: No, we did not vent The Keep's roof. We have no plans to breach the integrity of the container roof in any way. There is 1 to 1 1/2 feet of dirt on top of the container. The container has no leaks or inward bulging of its sides.

A reader from North Carolina wrote to ask about more details of The Keep, questions Bob-O responded to in this letter:

> *I don't know if the dynamics of burying a 40-foot container are different than for a 20-foot container (probably), but there are a number of things we have learned about it. Most of what you read says, "Don't do it!" in the first place. Maybe those people are right; time will tell.*
>
> *Kathleen and I live in a fairly dry climate. Twenty to 24 inches of rain is a good year for us and it rarely rains during the summer. In North Carolina, your mileage may vary.*
>
> *Containers are very strong in just five places—the corners and the floor. The sides and top are nearly unsupported thin metal and cannot handle the weight of wet earth without buckling. That's why we put old barn roofing on the three buried sides and roof, plus shored up the inside with 4-by-6 uprights and cross beams. Although it looks kind of like a mine shaft in there, this interior skeleton provides lots of places to hang things like onion bags.*
>
> *Between the cross beams, we strung 2-by-6 purlins lengthways. We used a hydraulic jack to push up the middle ones so the outer roof would be somewhat domed to help keep water from pooling on the roof.*
>
> *Annual ambient temperatures at our site range from about 10°F to 104°F. To combat this wide temperature swing, we built an insulated 2-by-6 wall about 2 feet inside the container with a good exterior door in it.*
>
> *Even though root-crop storage calls for much higher humidity than what is typical in the container, Kathleen says that her potatoes, onions, and carrots have never looked this good at this time of year.*

Ranging Around

I really have to thank all the people who took the time to e-mail me about my new propane range, and the anonymous female voice on my answering machine who explained how to adjust the burner flame.

My new friend Marty said it best. "I have converted a number of stoves from natural gas to propane and, without exception, even at minimum, the flames were way too high."

For those of you who are wrestling with adjustments, here are a few tips. The knobs pull off to reveal a set-screw about 2 to 2 1/2 inches inside the shaft. You'll need a 3/16-inch screwdriver to adjust the set-screw. Then:

1. Loosen the knob.
2. Light and set the burner to minimum. Then pull the knob off.
3. Adjust the flame to the desired height by turning the set-screw. (It can be pretty tough to adjust until you get a feel for it.)
4. Reinstall the knob, and turn off the burner.
5. Repeat for the remaining burners.

Several readers informed me that Peerless/Premier is going to discontinue their piezo electronic ignition models due to a small amount of mercury used in the controls. The government has made it a requirement to use glow bars in all ranges. This is an issue where one environmental issue conflicts with another environmental goal—saving energy. The least-expensive ranges already have glow bars; by June, all will be manufactured with them. The only way you will know is by the serial number, which will have a prefix to indicate it is a glow bar-equipped stove.

And On...

We are pleased with The Keep and I have adjusted my range burner so that now the flame can be lowered to simmer rather than boil. Our sights are set on new horizons in our personal quest for greater sustainability. Bob-O is making a series of portable cold frames to extend our growing season.

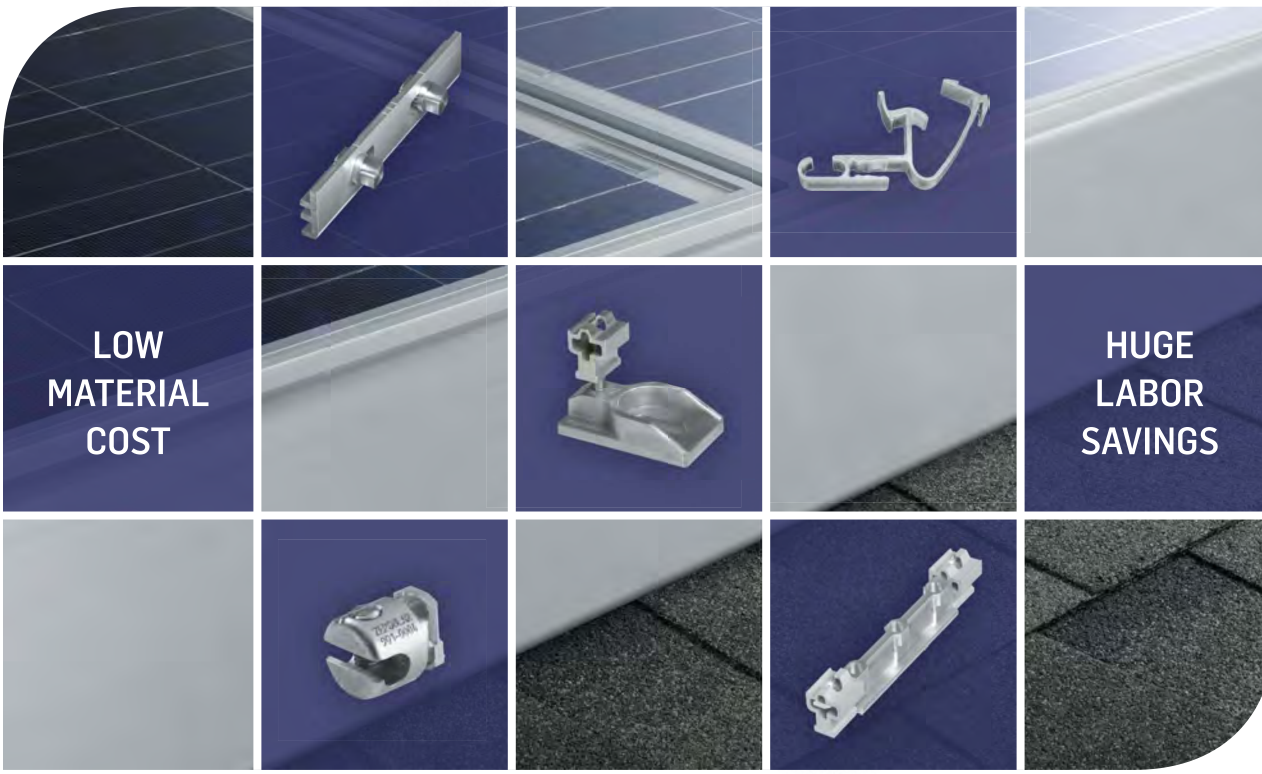
I have taken advantage of the huge "backyard chicken" movement to purchase a chicken coop kit from a local shed-building company. The Chicken House of Mystery (see *HP101*) will now become the Garden Toolshed of Mystery. My kit is the chicken coop I would have built, if I had known what I was doing. I have the parts, I have the instructions, and I have a cordless drill. The Poultry Palace promises a new efficiency in my free-ranging flock's care and management. Now, where did I leave that drill?

Access

Kathleen Jarschke-Schultze (kathleen.jarschke-schultze@homepower.com) is building a chicken coop and run, without mystery, at her off-grid home in northernmost California.

Zep Solar

Zep System II
PV Module Installation System



Zep System II Features:

- Eliminates Mounting Rails
- Ultra-safe Integrated Grounding
- Structurally Robust *(winds up to 150mph)*
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ZEP COMPATIBLE

Zep System II hardware is designed for use with Zep Compatible PV modules. Zep Compatible PV modules contain the patented Zep Groove frame design and interoperate with Zep Solar mounting and grounding hardware as well as other Zep Compatible installation accessories.

For a list of Zep Compatible PV modules, visit: **Zepsolar.com**

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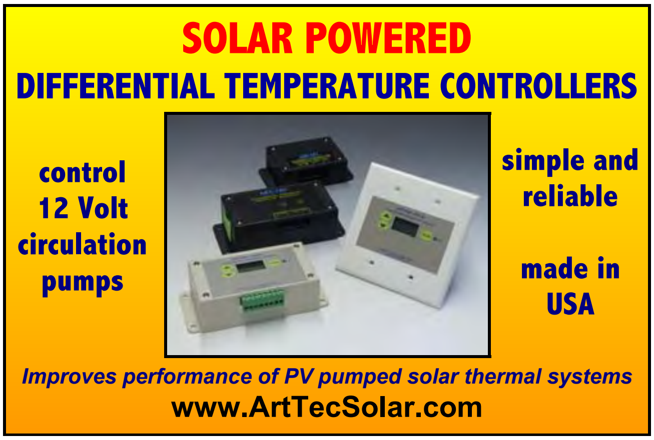
Zepulator

The Zepulator is a system design tool that allows you to configure arrays per site engineering requirements, generate bills of material, and produce project summaries for thorough permit submittals. Check out the Zepulator at: **Zepulator.com**

U.S. Patent #7,592,537, U.S. & Int'l Patents Pending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VAWTs & HAWTs

As a wind industry consultant, I get a lot of mail from folks with wind generator ideas. At least weekly, someone asks if I can give feedback on a design. More often than not, these are vertical-axis wind turbine (VAWT) schemes.

VAWTs come in a variety of configurations. The simplest homebrew Savonius models use a 55-gallon drum split in half vertically, with the two halves offset. Darrieus turbines, which look like giant eggbeaters, have shown up on experimental wind farms. But these machines are rare compared to common, tried-and-true horizontal-axis wind turbines (HAWTs).

VAWTs suffer from several technical challenges:

- Half of the swept area works against the wind
- Difficulty with start-up, shut-down, vibration, and fatigue
- Challenges with mounting on towers

For these reasons and others, many wind experts conclude that VAWTs will never be able to be as efficient or cost-effective as HAWTs. But perhaps more devastating to any possible success for these designs are the misconceptions and hype that surround them. The rhetoric includes common mythical comparisons to HAWTs, such as they:

- Don't need tall towers to produce significant energy
- Can be effectively mounted on buildings or on the ground
- Are better because they "take wind from any direction"
- Are better in low wind speeds
- Are better in turbulent winds

When examined in the light of physics and real-world experience, all of these ideas are substantially false.

VAWTs actually predate HAWTs, and mechanical vertical-axis "wind ma–chines" apparently existed more than 2,000 years ago. If VAWTs were the magic that their promoters suggest, I suspect that we would have seen success in the marketplace before now. The market is a great winnower of technology and can tell us what has promise. In the long run, people buy things that serve their needs—in this case, machines that actually generate useful amounts of energy over the long haul.

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Almost all of the turbines you'll find in productive, working systems are hori–zontal-axis. This is not because VAWTs have been suppressed, or that there's a conspiracy against them. It's because *HAWTs work better*! Decades of wind turbine design and experience show that HAWTs outperform VAWTs in energy pro–duction and reliability—as well as profitability for the manufacturers and installers.

Courtesy Kestrel Wind Turbines

Does a VAWT offer any advantages? I've been asking myself this question for many years. So far, the only true advantage I can see is aesthetics—some people like how these machines look. And aesthetics are important to most people. However, if aesthetics are the only true "advantage" of VAWTs, let's not put much emphasis on it. Or, we could remove the generator, make ourselves a "spinny thing" to entertain our aesthetic senses, and save a lot of money and avoid disappointment. Underperforming VAWTs (as with underperforming anythings) distract us from products that actually deliver.

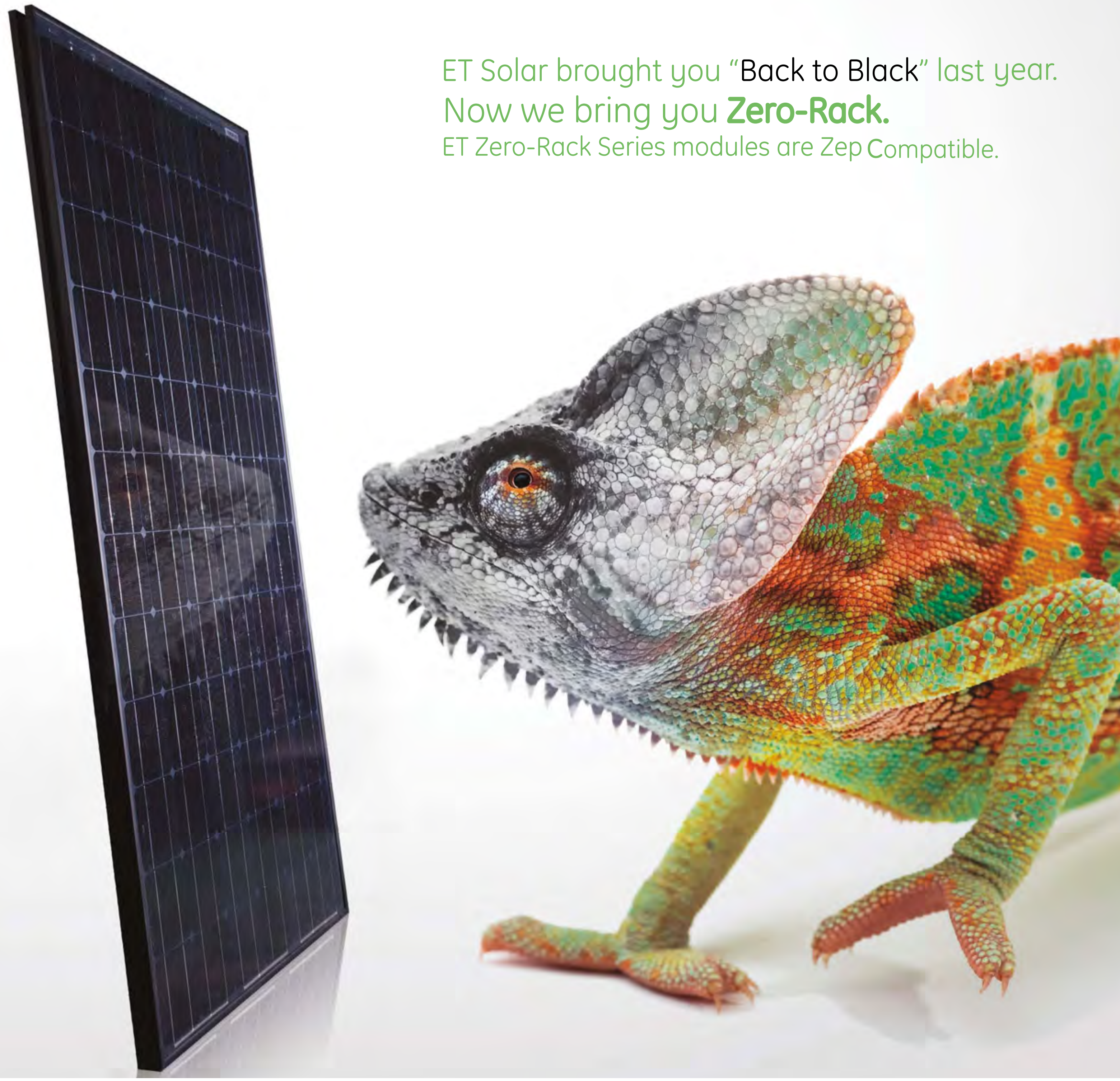
Perhaps some day we'll see a successful VAWT in the marketplace for more than a matter of years. Perhaps we'll see one that is durable and productive (though I don't expect a breakthrough, or an improvement over HAWTs). I remain open to this possibility, but remain guarded about the claims. *Caveat emptor*.

There's an easy test for whether a wind generator is worth buying or not. Find a system that has been installed for more than a year and get energy production numbers. Typically, when we ask VAWT salespeople for this info, they go scurrying to find a more gullible customer. But if you are trying to buy a machine to produce energy for you, it makes sense to verify how much energy it actually produces.

—Ian Woofenden

web extra

For more on the drawbacks and realities of VAWTs, see "Thoughts on VAWTs" (*HP104*) and "Ask the Experts" (*HP124*) online at **www.homepower.com/webextras.**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